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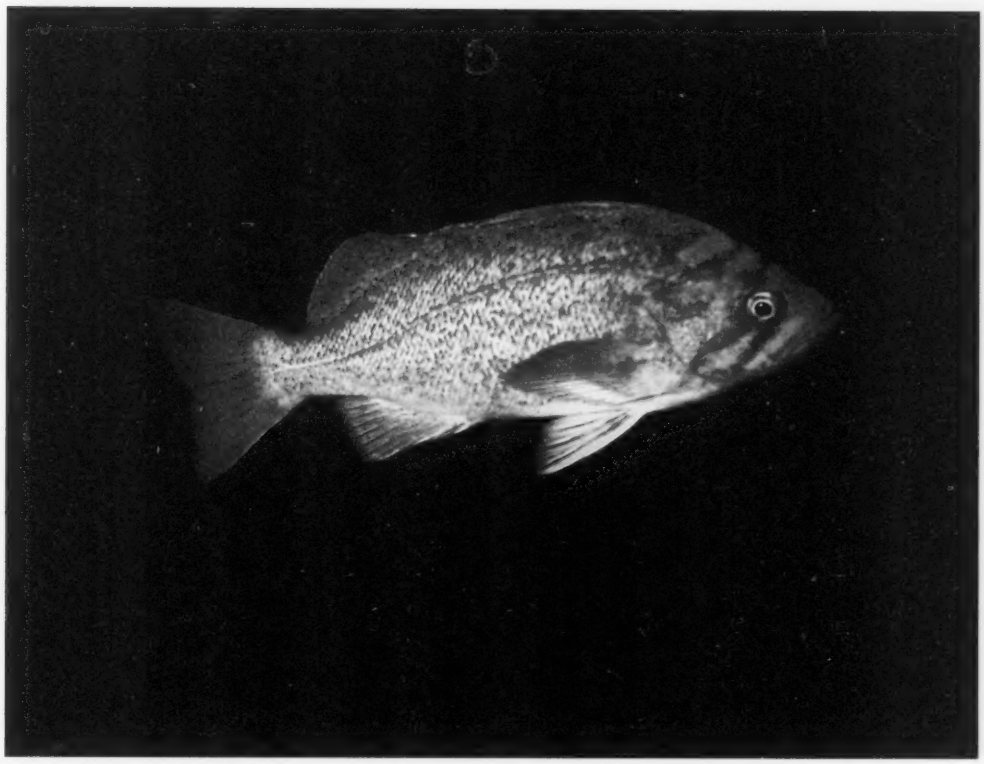

Monterey Bay Rockfish

Marine Fisheries REVIEW

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On the cover:
Blue rockfish, *Sebastes mystinus*, is one of the many rockfish species in Monterey Bay, California. Photo by Robert R. Lauth.

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Review of a Small-scale Pelagic Longline Fishery off Northeastern Brazil

F. H. V. HAZIN, J. R. ZAGAGLIA, M. K. BROADHURST, P. E. P. TRAVASSOS, and T. R. Q. BEZERRA

Introduction

The pelagic longline fishery off northeast Brazil began in 1956 with several Japanese longliners (leased by a Brazilian company) mainly targeting tunas (*Thunnus* spp.). This fleet consisted of 12 boats in 1959 (Paiva and Le Gall, 1975), and although quite good catches were achieved, fishing operations were suspended in 1964 owing to economic and political reasons. During 1976 and 1977, the fishery experienced a brief revival through the leasing of two Korean longliners; however, there was no significant effort until 1983 when a Brazilian company, "Norte Pesca," began to operate from Natal (Fig. 1) using relatively small vessels to target tunas and other large pelagic species of fish. This fleet expanded throughout the following 10 years and by 1997 consisted of 10 boats ranging in size from about 16 to 26 m.

As part of management regulations governing the present fishery, operators have been required to complete logsheets for each fishing trip. Information requested include location of fishing grounds, number of hooks used on the longline, time of setting and retrieving the gear, and composition of catches. In addition, at the end of fishing trips, biological data on the various species captured have routinely been collected by researchers. Although some of these data have been used in studies examining biological aspects of the main species, including their relative distribution and abundance (Hazin et al., 1990; 1994a), reproductive biology (Hazin et al., 1994b), and feeding habits (Hazin et al., 1994c), no studies have been done describing temporal and spatial variabilities in composition of catches.

To provide a brief overview of the changes in fishing strategy and catches, including some analysis of relative abundance and distribution of the main species, our aims in this paper were to collate yearly catch data from four vessels that have operated in the fishery since 1983 and compare these across defined areas and locations.

Material and Methods

This study was done using data from the logsheets of four longliners, (*Alfa*, *Argus*, *Rio Turi*, and *Soloncy Moura*) operating off northeastern Brazil from 1983 to 1997 (Fig. 1). All vessels used similar configurations of Japanese-style multifilament longlines (Shapiro, 1950; Suzuki et al., 1977). Each longline consisted of a multifilament mainline (Fig. 2A) with secondary lines (Fig. 2B) attached in clusters of 6–7 (termed "baskets") over approx. 360 m. Styrofoam bouys, each attached to a 25 m line were tied to the mainline after every cluster of hooks (Fig. 2A). The types of hooks used varied among 3 main brands (depending on availability) however, relative sizes remained similar throughout the period examined (Fig. 2C). The mean number of hooks (± SE) set per vessel per day was 975 ± 7. Fishing methods and operations were similar across the fleet with the mainline-set begining at about 0200 h and ending at dawn. The gear was then left to fish for about 6 h, before retrieval began at noon and ended at dusk. The primary bait was the Brazilian sardine, *Sardinella brasiliensis*, although some other species, including flying fish, *Cypselurus cyanopterus*, and squid, *Loligo* sp., were occasionally used.

Due to different oceanographic and biological conditions (Paiva and Le Gall, 1975; Hazin[1]) and for the purposes of this study, the total area fished (Fig. 1) was divided into the following three subareas for analysis:

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ABSTRACT—The annual catches of four small longliners operating off northeast Brazil from 1983 to 1997 were examined across different areas and locations. The total catch comprised tunas (30%), sharks (54%), billfishes (12%), and other fish species (4%). Fishing strategy and annual composition of catches showed large spatial and temporal variabilities with the dominant catches alternating among yellowfin tuna, Thunnus albacares*; gray sharks,* Carcharhinus *spp.; and blue shark,* Prionace glauca*. Catches of blue and gray sharks showed a significant interaction among seamounts, with gray sharks occurring in maximum abundance around those seamounts that had relatively deep summits and low-sloping depth profiles. Results are discussed in terms of the various factors that may have influenced distribution of effort.*

[1] Hazin, F. H. V. 1993. Fisheries-oceanographical study on tunas, billfishes and sharks in the southwest equatorial Atlantic Ocean. D. Sc. Thesis, Tokyo Univ. Fish., 286 p.

Subarea I (north of lat. 5°S and west of long. 35°W) contains several large seamounts comprising the North Brazilian Chain and is influenced by the North Brazil Current.

Subarea II (north of lat. 5°S and east of long. 35°W) contains Atol das Rocas, Fernando de Noronha, and the Archipelago of St. Peter and St. Paul and is influenced by the South Equatorial Current.

Subarea III (south of lat. 5°S) includes a deep oceanic area with no seamounts or islands and is influenced by the Brazil Current.

Data from the four boats were grouped together (to provide a larger dataset) and total catches were standardized to yearly catch per unit of effort (CPUE), defined as the number of fish caught per 100 hooks per year (no. of fish/100 hooks/year). Catch records included identification at the species level, with the exception of sharks, which were collectively grouped prior to 1986. Most fishermen included catches of individual species during subsequent trips, although it wasn't until 1990 that all provided these data. Consequently, while the CPUE of total sharks was calculated using all hooks set in each year (Table 1), the CPUE of individual species of sharks was derived using the number of hooks pooled across only those trips that included a complete tabulation of catches (Table 2). In addition, because of difficulties in distinguishing some of the species of the genus *Carcharhinus*, for the purposes of this study, these were grouped under the category of "gray sharks," with the exception of *C. maou*, due to its easily identifiable characteristics. Data for two species of mako sharks (*Isurus oxyrinchus* and *I. paucus*) were also combined.

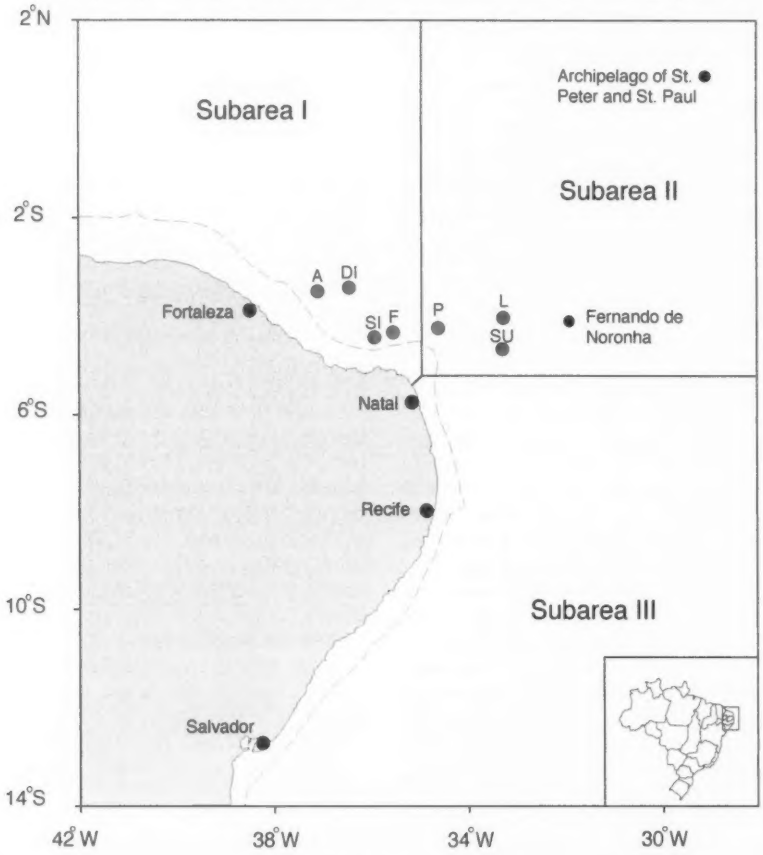

Figure 1.—Location of the area fished during the period examined, including the approximate position of seamounts: Aracati (A), Dois Irmãos (DI), Fundo (F), Sirus (SI), Pequeno (P), Leste (L), and Sueste (SU).

Analysis of Data

To examine temporal and spatial fluctuations in relative abundance and distribution throughout the fishery, yearly estimates of CPUE for groups of species were calculated for each of the three areas. Further, because significant differences were detected in the CPUE of sharks between areas (see Results and Discussion) the yearly CPUE's of gray and blue sharks, *Prionace glauca*, were calculated at seven seamounts located in subareas I and II (Fig. 1, Table 3). In deriving these data, longlines were considered to be in the vicinity of a seamount whenever they were located within 5 n.mi. of the 1,000 m isobath.

Yearly CPUE values for relevant groups and species from each area and for gray and blue sharks from each seamount were analyzed using Cochran's test for homogeneity of variances. Data were transformed if necessary and then analyzed in appropriate one and two-factor analyses of variance, respectively (Underwood, 1981). Significant differences detected in these analyses were investigated using Tukey's multiple comparisons of means test. The arithmetic mean yearly CPUE's used in these analyses are presented with their associated standard errors. Total yearly CPUE's combined across all areas, depths, and locations for all groups and species that showed sufficient catches were also calculated and graphed.

Results and Discussion

The yearly catch data collected during the period examined are provided in Tables 1 and 2. Tunas and sharks, and in particular, yellowfin tuna, *Thunnus albacares*, and gray and blue sharks were the dominant groups, accounting for almost 84% of the total catch.

There were no significant differences in the arithmetic mean yearly CPUE's of total tunas and billfishes across the three subareas examined (Fig. 3A, B, Table 4). While differences were de-

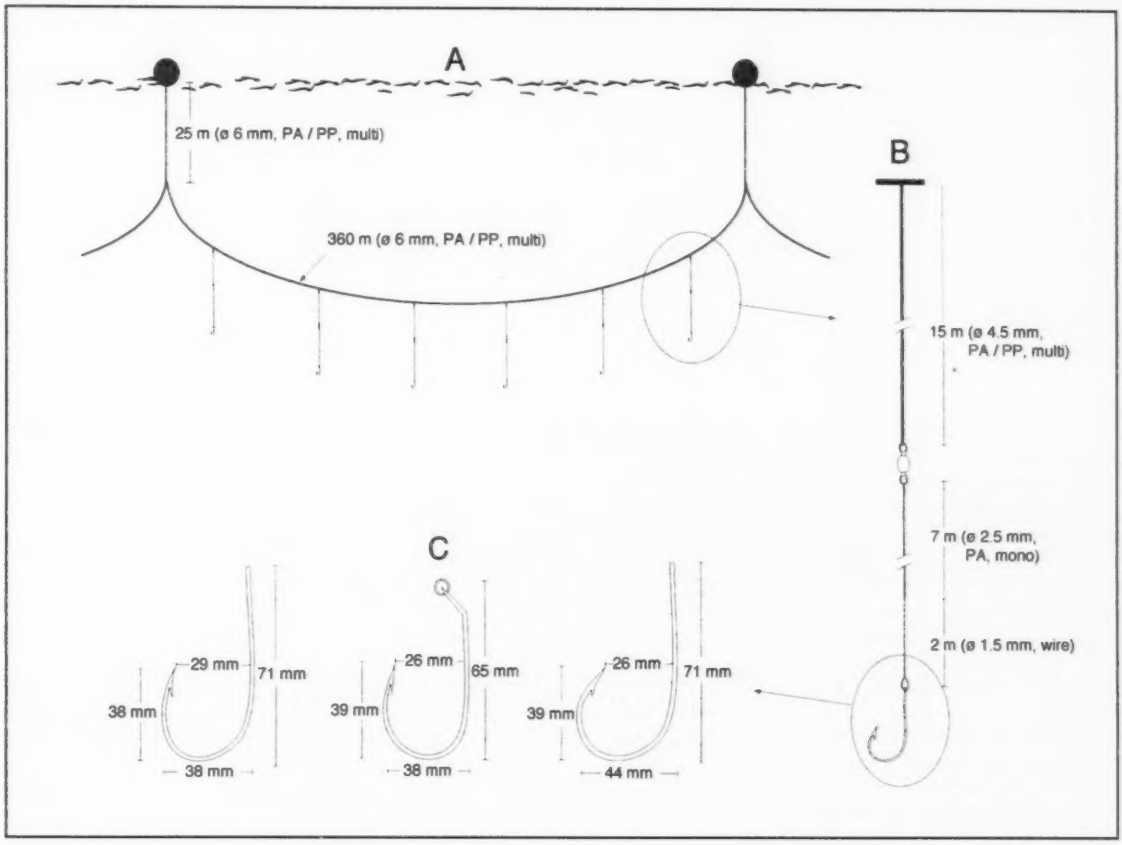

Figure 2.—Diagrammatic representation of typical (A) longline configuration; (B) secondary line; and (C) hooks used by the four vessels over the period examined. ø = diameter, mono = monofilament, multi = multifilament, PA = polyamide, PP = polypropylene.

Table 1.—Annual number of hooks used and catches (from 1983 to 1997) for various species and groups.

Year	Number of hooks	Tunas			Billfishes				Total sharks	Other fish combined
		Yellowfin	Albacore	Bigeye	Swordfish	Sailfish	White marlin	Blue marlin		
1983	34,719	129	194	16	23	10	42	9	156	228
1984	98,295	1,039	465	66	136	124	407	26	681	320
1985	222,738	1,827	666	158	276	142	240	83	1,381	379
1986	543,198	3,622	1,053	312	433	210	762	122	3,267	615
1987	513,427	1,906	418	347	443	243	452	84	5,835	448
1988	399,640	3,399	159	438	483	129	234	57	4,270	350
1889	275,526	3,973	182	207	361	76	217	74	2,054	143
1990	273,700	1,630	177	126	305	74	146	36	1,883	522
1991	101,670	868	51	40	135	11	37	21	970	53
1992	130,912	606	42	17	276	27	42	16	2,591	54
1993	89,222	93	0	1	169	8	16	10	3,371	35
1994	116,964	973	5	11	270	62	51	18	3,347	1
1995	172,100	597	21	4	555	16	25	18	8,394	12
1996	229,888	246	12	22	1,298	173	67	36	7,162	300
1997	74,060	72	6	9	280	20	21	13	1,738	17

tected between mean CPUE's of other fish combined (Fig. 3C, Table 4). Tukey's tests showed no definitive order of catches among the three subareas (Fig. 3C). In contrast, analyses showed that the mean CPUE of total sharks was significantly greater in subarea I than in subareas II and III (difference between means of up to 68%) (Fig.

Table 2.—Annual number of hooks used and catches (from 1986 to 1997) for individual species of sharks.

Year	Total no. of hooks	Blue (*Prionace glauca*)	Gray (*Carcharhinus* spp.)	Bigeye thresher (*Alopias superciliosus*)	Mako (*Isurus* spp.)	Ocean whitetip (*C. maou*)	Crocodile (*Pseudocarcharias kamoharai*)	Other shark species
1986	147,237	715	221	2	41	0	30	286
1987	338,704	1,345	973	18	74	18	21	41
1988	399,430	2,503	1,489	50	103	78	0	26
1889	274,126	945	934	11	56	63	0	37
1990	273,700	986	771	13	56	23	15	19
1991	101,670	360	577	6	9	15	1	2
1992	130,912	177	2,392	7	8	6	1	0
1993	89,222	105	3,212	5	8	0	0	41
1994	116,964	192	3,122	11	7	9	0	6
1995	172,100	238	8,082	15	24	5	0	30
1996	229,888	732	6,231	5	26	36	0	132
1997	74,060	263	1,455	0	8	7	0	5

3D, Table 4). This increase in CPUE may be attributed to the significant increase in catches of gray sharks in subarea I and the effects on total catches of sharks, since their mean CPUE was 9 times lower in subarea II and almost zero in subarea III (Fig. 3E, Table 4). Although much lower, the catches of blue sharks displayed the opposite trend and were significantly greater in subareas II and III than in subarea I (Fig. 3F, Table 4).

Possible explanations for the observed anomaly between the CPUE of gray and blue sharks may be the fishing location in subarea I and species-specific variabilities in habitat preference (Hazin et al., 1990). For example, unlike subareas II and III, which mainly comprise deep ocean, many of the sets in subarea I were done in the vicinity of seamounts that were relatively shallow over large areas (see Table 3). Because previous studies have shown that the blue shark typically is an oceanic species, its relative abundance might be expected to decline across these areas (Strassburg, 1958; Hazin, et al., 1990). In support of this, the mean CPUE of blue sharks was consistently low across individual seamounts (Fig. 4) and showed little variability since Tukey's test for a significant interaction detected between seamounts and groups of sharks (Table 5) failed to detect any significant differences in mean CPUE of this group among the seamounts examined (Fig. 4, Table 5).

Conversely, the CPUE of gray sharks did show an effect due to seamounts and was significantly greater (difference between means of up to 95%) at those seamounts that had relatively deep summits (e.g. 233–370 m) and were shallow over a large area (i.e. Aracati, Dois Irmãos, Fundo, and Sirus) than those characterized by shallow summits (38–176 m) and steep depth profiles (i.e. Pequeno, Leste, and Sueste). In the absence of any data describing oceanographic conditions and habitats at these different types of seamounts, it is difficult to determine possible causes for the observed increase in CPUE at the seamounts with deeper summits and low-sloping depth profiles. Previous studies have shown, however, that seamounts in this category may have more turbulence, due to the interaction between oceanic currents and the submarine relief, that results in the formation of upwellings and possibly "Taylor Columns" (Rogers, 1994; Travassos et al., In press). The extent to which these sorts of processes may facilitate primary production and consequent cascading effects throughout the trophic chain is unknown but, given the observations in the present study, they may have had some influence that contributed to the greater relative abundance of gray

Table 3.—The approximate location (midpoint) of seamounts examined, depth at the summit, and area contained within 5 n.mi. beyond the 1,000 m isobath. Seamounts in bold represent those located in subarea I.

	Seamount						
Item	**Aracati**	**Dois Irmãos**	**Fundo**	**Sirus**	Pequeno	Leste	Sueste
Location (lat.)	**3°20' S**	**3°20' S**	**3°52' S**	**4°00' S**	3°50' S	3°45' S	4°16' S
(long.)	**37°30' W**	**36°38' W**	**35°22' W**	**35°55' W**	34°44' W	33°12' W	33°15' W
Depth at summit (m)	**254**	**370**	**214**	**233**	124	176	38
Area (km^2)	**4,837**	**1,110**	**2,815**	**5,075**	833	952	833

Table 4.—Summaries of *F* ratios from analysis of variance to determine effects on CPUE due to different areas for total tunas, sharks, billfishes, and other fish combined between 1983 and 1997 and for blue and gray sharks between 1987 and 1997. Because 5 and 3 replicate CPUE data were missing from each analysis respectively, we substituted means of the remaining replicates and reduced the degrees of freedom accordingly. The transforms used to stabilize variances (if required) are also listed. *significant ($P = 0.05$); **significant ($P = 0.01$).

Source of variation	df	Total tunas	Total billfishes	Total sharks	Other fish combined	df	Blue shark	Gray shark
		ln(x+1)		ln(x+1)				ln(x+1)
Area	2	0.37	0.75	14.54**	4.482*	2	22.50**	36.60**
Residual	37					30		

Table 5.—Summaries of *F* ratios from analysis of variance to determine effects on yearly CPUE for two groups of sharks and different seamounts. Because 10 CPUE data were missing, we substituted means of the remaining replicates and reduced the degrees of freedom accordingly. The sqrt(x+1) transform was used to stabilize variances. **significant ($P = 0.01$).

Source of variation	df	CPUE
Seamount	6	6.38**
Shark group	1	97.57**
Interaction	6	14.36**
Residual	130	

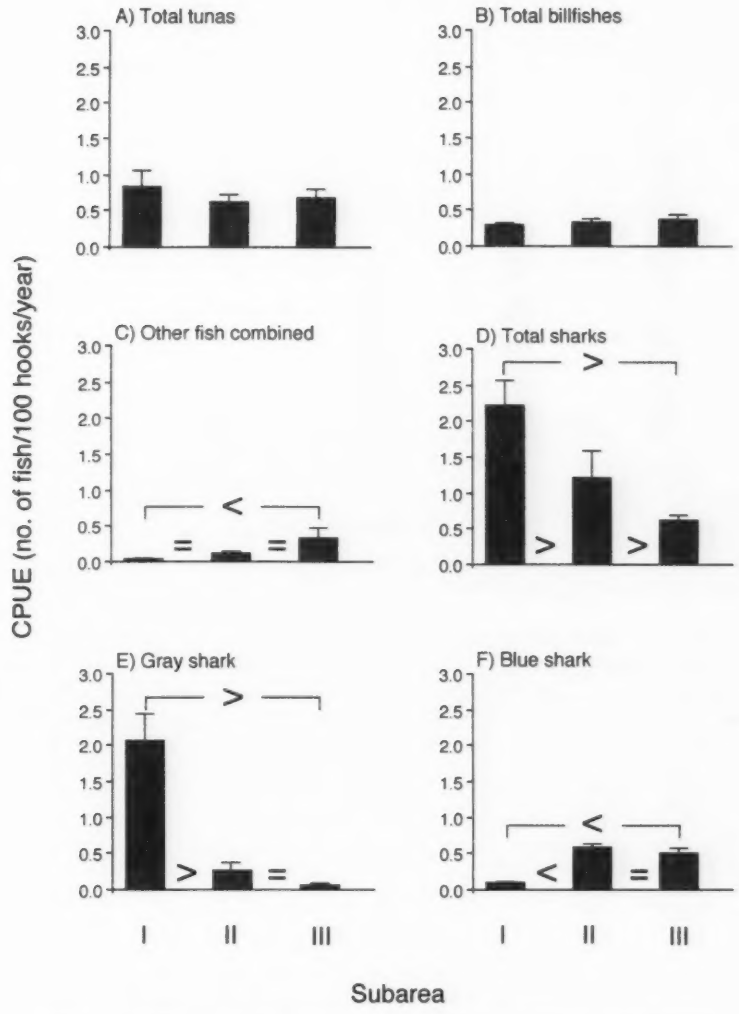

Figure 3.—Differences in arithmetic mean yearly CPUE (±SE) of (A) total tunas, (B) total billfishes, (C) other fish combined, (D) total sharks, (E) gray shark, and (F) blue shark across each of the three areas. <, >, and = indicate direction of differences detected in Tukey's comparison of means test.

sharks in subarea I and the significant increase in their CPUE.

The data presented in Figures 5, 6, 7, and 8 show quite large temporal fluctuations of total yearly CPUE (combined across all areas and depths) of most groups and species examined. For example, with the exception of the first year of the fishery, yellowfin tuna was always the most abundant species of tuna, with a yearly CPUE varying from 1.44 in 1989 to 0.10 in 1997 (Fig. 6). The CPUE of albacore, *Thunnus alalunga*, showed less variability but steadily decreased from 0.56 in 1983 to 0.001 in 1993, whilst the yearly CPUE of bigeye tuna, *T. obesus*, was always very low (Fig. 6). Catches of gray and blue sharks showed similar fluctuations with blue shark most abundant from 1986 until June 1991 before the CPUE of gray sharks began to increase, peaking in 1995 (Fig. 7). Although total catches of billfishes remained fairly stable (Fig. 5), individual catches of swordfish, *Xiphias gladius*, steadily increased from 1991 (Fig. 8).

Many of these temporal variabilities can be explained with respect to changes in overall fishing strategy over the past 14 years, summarized in 5 distinct periods:

Period 1 (July 1983–June 1986). Tunas (i.e. mainly yellowfin tuna) and

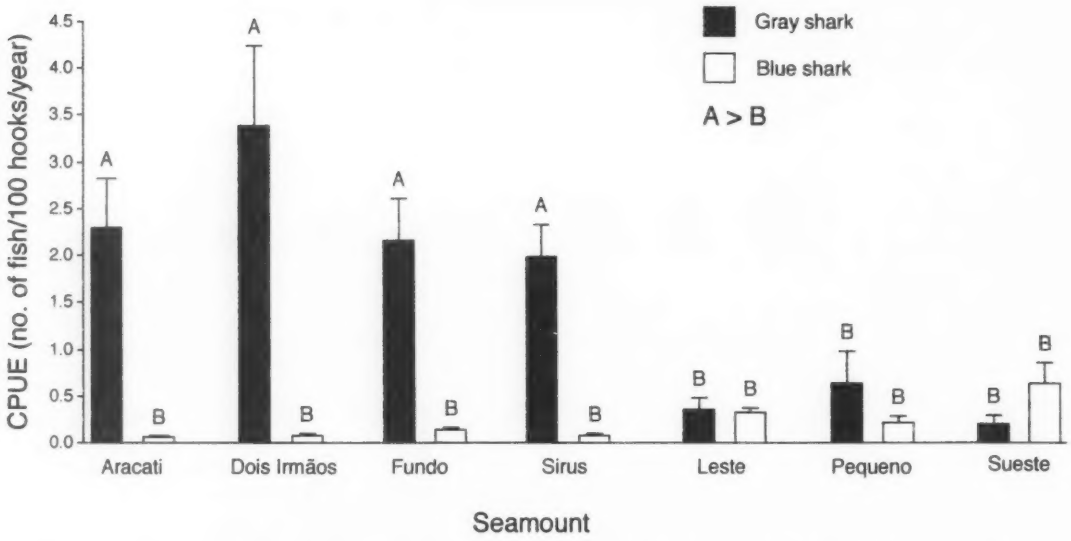

Figure 4.—Differences in arithmetic mean yearly CPUE (±SE) of (A) gray shark, and (B) blue shark across different seamounts. <, >, and = indicate direction of differences detected in Tukey's comparison of means test.

billfishes (swordfish, sailfish, *Istiophorus albicans*, white marlin, *Tetrapturus albidus*, and blue marlin, *Makaira nigricans*) were the main target groups whilst sharks were avoided.

Period 2 (July 1986–December 1987). Along with tunas and billfishes, sharks (mainly the blue) became a target group.

Period 3 (January 1988–June 1991). Fishing grounds were discovered off the Archipelago of St. Peter and St. Paul, with associated increases in catches of yellowfin tuna, shifting effort towards this species.

Period 4 (July 1991–June 1996). Fishing effort was concentrated over shallow seamounts, where species comprising gray sharks were abundant. Catches were mainly dominated by these sharks.

Period 5 (July 1996–June 1997). Although gray sharks were still the dominant group, the CPUE of swordfish rose sharply owing to a concentrated effort involving the use of light sticks above the hooks and squid as bait.

The initial diversification in effort that resulted in sharks being included as a target group (period 2) mainly occurred because of an increased awareness of their abundance and availability. In contrast to many international longline fisheries, which tend to remove the fins and discard the carcass at sea, in this fishery all shark carcasses are landed and sold at the local market. However, because of the low price of their meat, prior to June 1986 the return paid to fishermen was half that for tunas and billfishes. In July 1986, the fishing company standardized the return for all species caught after it realized that although sharks were worth less than other species, their abundance meant that production could be more than doubled. Facilitating this diversification of effort was an established local market for shark products, (e.g. frozen fillets) that had developed from the steady production of shark meat during the first 3 years of the fishery.

From January 1988 and during the first quarter of each consecutive year (period 3), vessels began to operate in the vicinity of the Archipelago of St. Peter and St. Paul to target yellowfin tuna that aggregate in large numbers to feed on dense schools of spawning flying fish (Hazin[1]). As a result, the CPUE of this species more than tripled in the first 2 years after the new fishing grounds were discovered (Fig. 6). This contributed to an overall rise in the CPUE of total tunas (Fig. 5) and also resulting in a slight drop in the CPUE of sharks (1988–90) due to a shift in effort away from their areas of maximum abundance (i.e. the seamounts in subarea I) (Fig. 5).

After 1992 (during period 4), vessels concentrated around the many seamounts mainly located in subarea I to target gray sharks (Fig. 7). Contributing factors towards the greater shift in effort on this group were 1) the discovery of large abundances of these individuals above those seamounts in subarea I that are shallow over a large area (see discussion above) and 2) an increase in the price of shark fins for international markets.

Prompted by the leasing of an American swordfish longliner, vessels began to shift fishing effort again during mid 1996 (period 5), using light sticks above the hooks and squid as bait to target swordfish. Recent modifications to gear, particularly the use of monofilament mainlines, should see this trend increase as fishermen adopt the latest technology and methods developed in other fisheries (Bjordal, 1989; Løkkeborg and Bjordal, 1992).

It is apparent that a number of factors have contributed to changes in fishing strategy during the past 14 years. Many of the shifts in effort appear to

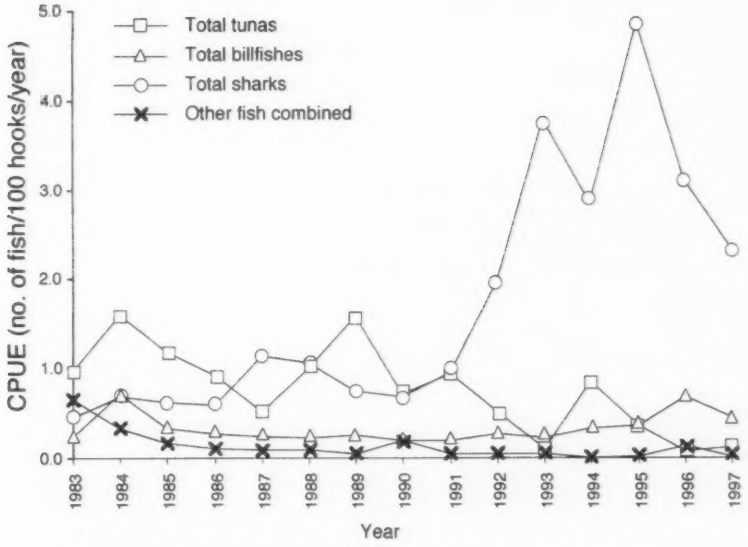

Figure 5.—Yearly CPUE estimates of total tunas, billfishes, sharks, and other species combined throughout the period examined.

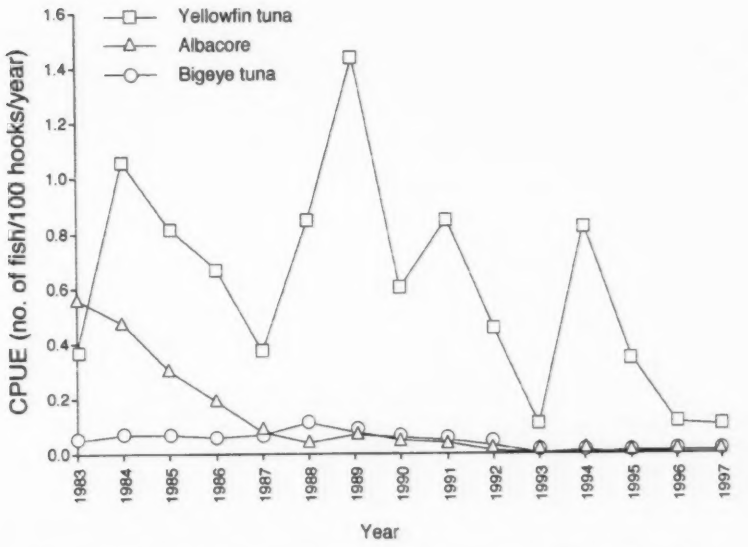

Figure 6.—Yearly CPUE estimates of yellowfin tuna, albacore, and bigeye tuna throughout the period examined.

have been either market orientated, reflecting variabilities in consumer demand for various species, or as a result of the discovery of new fishing grounds and stocks. While few, if any, of the changes in the first 13 years are gear related, given some of the more recent developments (e.g. use of monofilament) and that most of the fishing areas have been fully explored, these sorts of changes are likely to affect CPUE in the future. It is important, therefore, for the continued sustainability of the fishery, that monitoring of catch and effort data is maintained.

Acknowledgments

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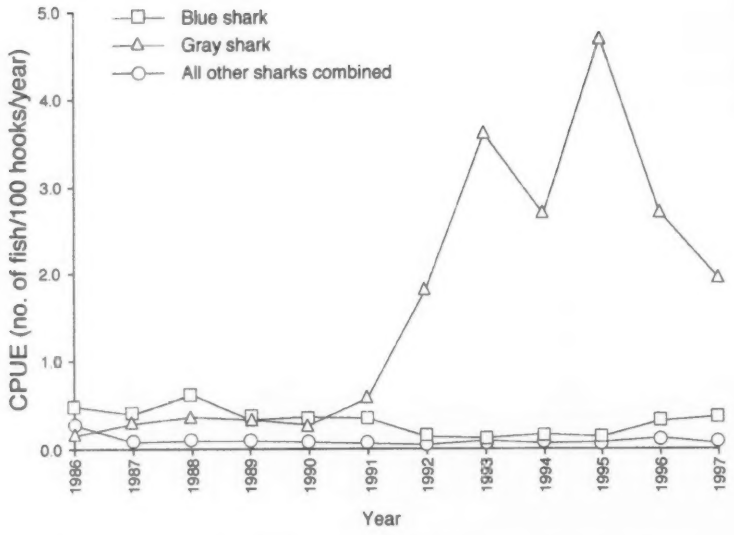

Figure 7.—Yearly CPUE estimates of gray shark, blue shark, and other sharks combined throughout the period examined.

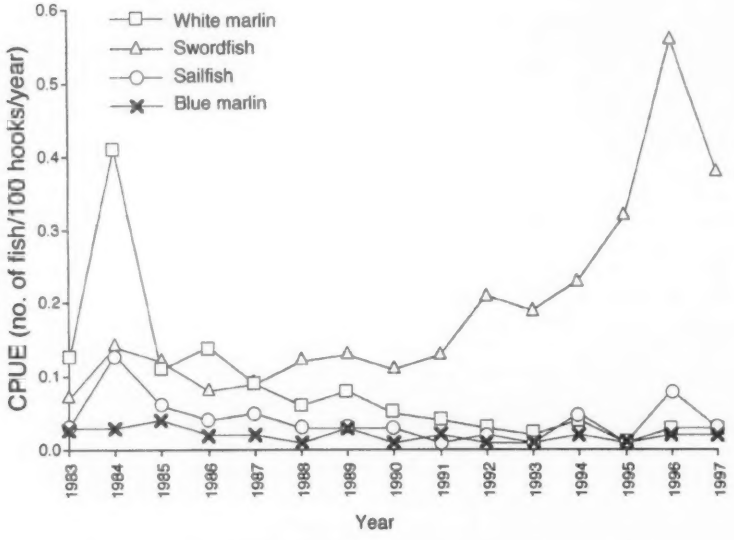

Figure 8.—Yearly CPUE estimates of white marlin, swordfish, sailfish, and blue marlin throughout the period examined.

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Bottlenose Dolphins, *Tursiops truncatus*, Removing By-catch from Prawn-trawl Codends During Fishing in New South Wales, Australia

M. K. BROADHURST

Introduction

Like the majority of otter trawls, prawn trawls typically are poorly selective fishing gears, and in addition to the targeted species they also catch and retain large quantities of nontarget species (termed by-catch), which often comprises a diverse assemblage of small fish, crustaceans, and cephalopods (for reviews see Andrew and Pepperell, 1992; Kennelly, 1995). While some of this by-catch may be retained and sold commercially (Broadhurst and Kennelly, 1997), large quantities are often discarded at sea.

Several studies have examined the fate of discarded by-catch from prawn trawling and show that in some cases it may contribute significantly to the diets of various scavenging predators, including seabirds (e.g. *Phalacrocorax varius, P. melanoleucos, Anous stolidus, Sterna bergii,* and *S. hirundo*) (Blaber and Wassenburg, 1989; Hill and Wassenburg, 1990; Blaber et al., 1995), crustaceans (e.g. *Portunus pelagicus*) (Wassenburg and Hill, 1987; 1990), fish (e.g. *Nemipterus* spp. and *Pentapodus* spp.), sharks (*Carcharhinus* spp.) (Hill and Wassenburg, 1990), and dolphins (e.g. *Tursiops truncatus*) (Leatherwood, 1975; Corkeron et al., 1990; Hill and Wassenburg, 1990). Many of these studies have used either visual census or underwater camera and video, at the surface and on the sea bed, to document the feeding behavior of various predators scavenging by-catch discarded from prawn trawlers. There is also some anecdotal evidence to suggest that some predators, such as bottlenose dolphins, *Tursiops truncatus*, may feed at prawn trawls during towing (Leatherwood, 1975), however, there is an absence of information and visual evidence on the extent to which these sorts of predators interact with the trawl. This communication documents one such interaction by providing the first videographic evidence of dolphins at the sea bed actively manipulating the codend of a prawn trawl to remove by-catch.

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ABSTRACT—During a fishing trip to record video footage of fish escaping from a by-catch reducing device located in a commercial prawn trawl, two bottlenose dolphins, Tursiops truncatus, *were observed to actively manipulate the codend at the seabed, removing and consuming components of catch (mostly juvenile whiting,* Sillago *spp.). The observed feeding pattern suggests a well established behavioral response to trawling activities and is discussed with respect to (1) the potential nutritional benefit that dolphins may derive from such activities and (2) the effects that scavenging may have on selectivity of the gear.*

Materials and Methods

These observations were made at night onboard a commercial prawn trawler (13.8 m) fishing on grounds northeast of Yamba, New South Wales (NSW), Australia (Fig. 1) in September 1996 during a trip to record film of fish escaping from a composite square-mesh panel (a by-catch reducing device developed for NSW oceanic prawn-trawls—Broadhurst and Kennelly, 1996; 1997). Three Florida flyers (mesh size 42 mm) each with a headline length of 12.8 m were rigged in a triple gear configuration and towed at 2.5 knots in depths ranging from 18 m to 22 m. The starboard outside net was fitted with a codend containing a composite square-mesh panel (Fig. 2). A "Photosea cobra" underwater video camera was mounted over the anterior section of the composite square-mesh panel, facing aft along the top of the codend (Fig. 2). This camera was linked, via coaxial cable, to a control console and PAL video monitor onboard the vessel and supplied with 240 volts of electricity. Two 240 watt submersible lights, facing aft, were mounted anterior to the camera on either side of the codend (Fig. 2). These lights were necessary since the camera was used at night with zero visibility. The nets were set and towed according to normal commercial operations with the camera switched on immediately after the gear touched the sea bed and then turned off again prior to hauling.

Results and Discussion

During three successive 60–90 min tows during the night, approximately 10–20 min after the camera was switched on and shortly after the lights were activated (providing a visibility of about 1.5–2 m), two bottlenose dolphins were ob-

served to be in the process of slowly approaching the posterior end of the codend (Fig. 2 and 3A). The dolphins swam directly into the rear of the codend and using their rostrums and foreheads, pushed the diamond-shaped meshes forward and up with considerable force (Fig. 3B). This movement displaced the catch forward, effectively increased the fractional mesh openings in the codend, and resulted in the release of large numbers of small organisms and fish, mostly juvenile whiting (*Sillago* spp.). The dolphins retreated and consumed some of these fish as they drifted from the codend (Fig. 3C) and also, by tilting their heads laterally, swam forwards and actively removed other individuals that were trapped between meshes. This behavior was repeated for up to 20 minutes during each tow. The dolphins were not observed to chase nor consume any of the live whiting that were escaping from the composite-square mesh panel. These fish tended to rise up above the dolphins and were quickly lost from view.

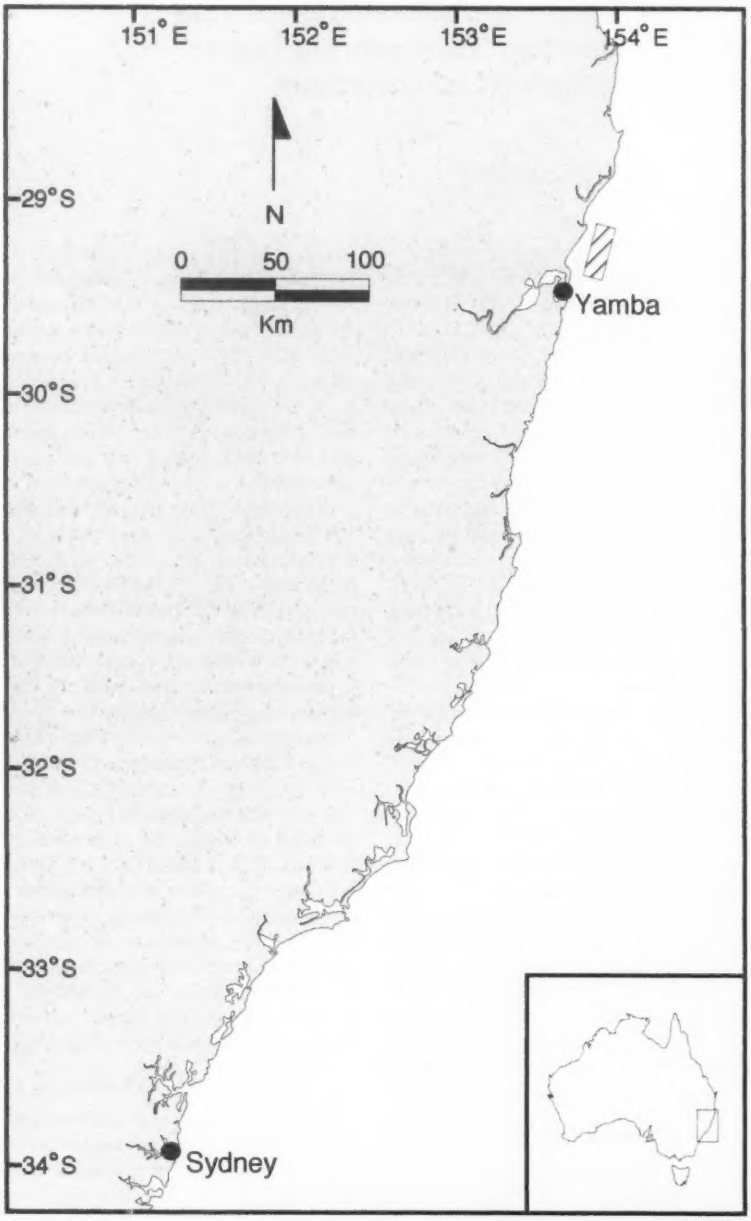


Figure 1.—New South Wales coast and location of area trawled.

To determine if the lights attached to the camera had any contributing effect towards behavior, they were switched off (resulting in zero visibility), for up to 45 seconds, and then on again. This was repeated 7 times while the dolphins were at the codend, but had absolutely no effect on their feeding pattern, indicating that their behavior was well established. For example, at the exact moment the lights were switched on, the two dolphins were observed to be either in the process of (i) actively removing fish from the codend, (ii) forcing the codend forwards and upwards, or (iii) consuming fish that were released as a result of the previous action. Further, on two occasions when there were no dolphins at the codend, the lights were switched off for approx. 5 mins and then on again, revealing two dolphins displaying the same routine behavior as that discussed above.

Because it was necessary to turn the camera off prior to hauling the trawls, it was not possible to determine if any dolphins followed the codends to the surface. However, at the end of each tow up to 5 bottlenose dolphins were observed foraging around the vessel and at the trawl while the codends and camera were brought aboard. These individuals remained in close proximity while the catch was sorted, disappearing only when the vessel was underway and setting of the trawls began. It is possible that they followed the trawls to the seabed, although I have no evidence to support this hypothesis.

Bottlenose dolphins are endemic to many coastal areas throughout the world's tropic and temperate waters (Jefferson et al., 1993). They are regarded as catholic feeders, consuming

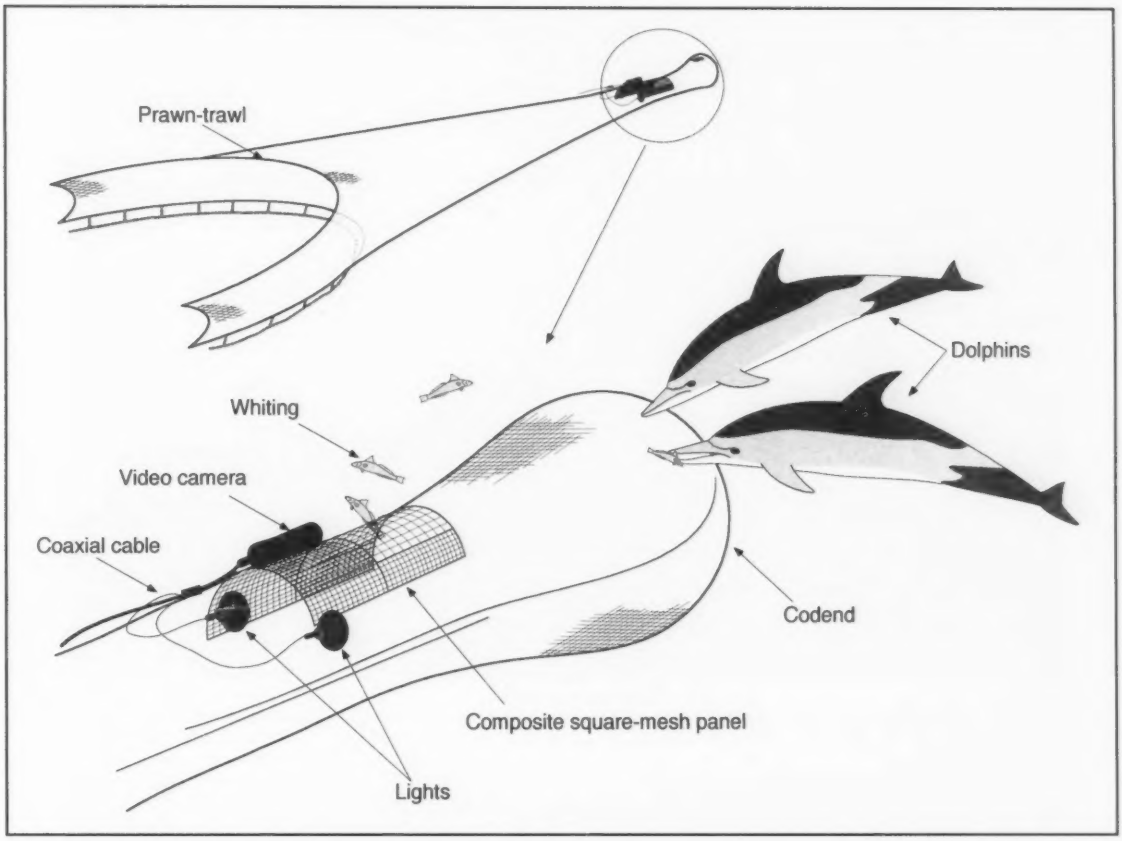


Figure 2.—Diagrammatic representation of prawn trawl, codend, location of camera and lights, and position of dolphins.

a range of fish and cephalopods (Corkeron et al., 1990; Santos, et al., 1994) and have frequently been observed to congregate and feed in close proximity to trawling operations (e.g. Leatherwood, 1975; Corkeron et al., 1990; Hill and Wassenburg, 1990; Shane, 1990). This latter observation is a common occurrence in NSW and in over 175 and 100 days spent onboard prawn and fish trawlers, respectively (operating both at night and during the day), I have regularly observed bottlenose dolphins at the surface either (1) removing catch from codends while the trawls were retrieved or alternatively, (2) scavenging the catch discarded during sorting. Although there are no published records of the types of species consumed by dolphins during these encounters in NSW, in another study Corkeron et al. (1990) examined the behavior of bottlenose dolphins feeding on by-catch discarded from prawn trawlers in Moreton Bay, QLD and concluded that while individual preference played a major role in determining what was eaten, several species, including whiting, *Sillago maculata*, flathead, *Platycephalus* sp., and squid, *Loligo* spp., were often consumed while crustaceans were always ignored.

In the present study, repeated manipulation of the codend and the associated routine feeding pattern was observed to occur for up to 20 minutes during each tow. It was not possible to quantify the amount of small organisms released from the codend nor the amount of fish consumed by the dolphins during this period, however, previous studies discussed by Shane (1990) suggest that an adult bottlenose dolphin may consume between 4% and 6% of their body mass daily. A mature dolphin, 2.5 m long and weighing approximately 200 kg (Mead and Potter, 1990), therefore, could consume up to 12 kg of fish per day or the equivalent of 300 of the small whiting (40 g) or other similar-sized individuals of species that frequently appear in by-catches of trawlers working throughout the geographic range of the NSW oceanic prawn-trawl fishery (Broadhurst and Kennelly, 1997). This information, when considered along with the size of the prawn-trawl fleet in NSW (300 vessels) and their gear configuration (3 nets) illustrates the potential for dolphins to derive a substantial nutritional benefit from interactions with prawn trawls.

Despite the evidence to suggest that dolphins occur in close proximity to trawling operations off NSW and inter-

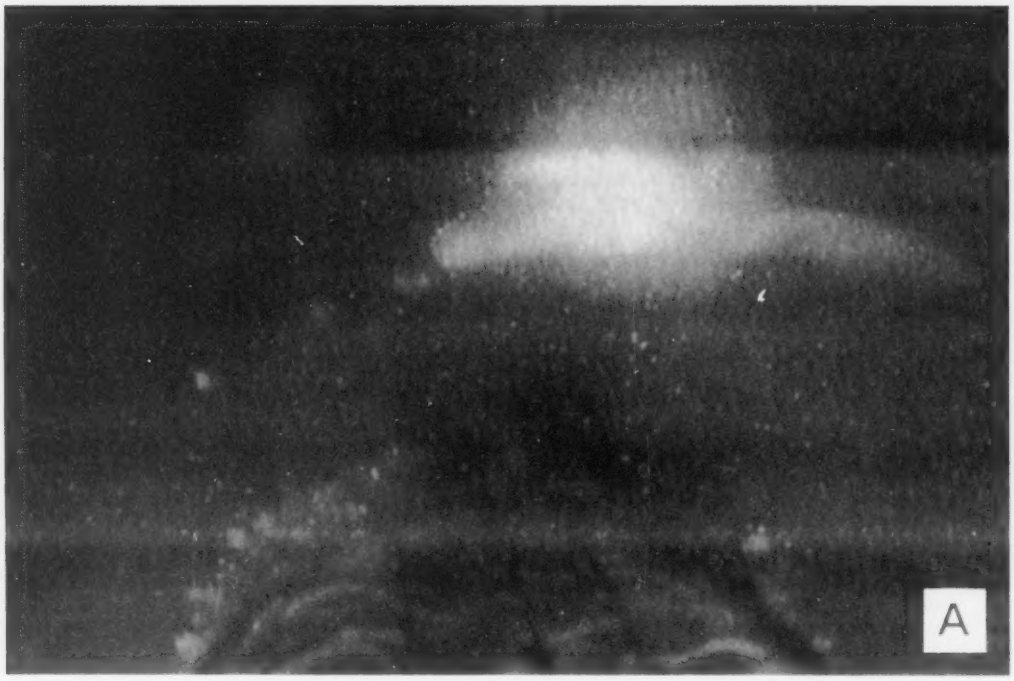


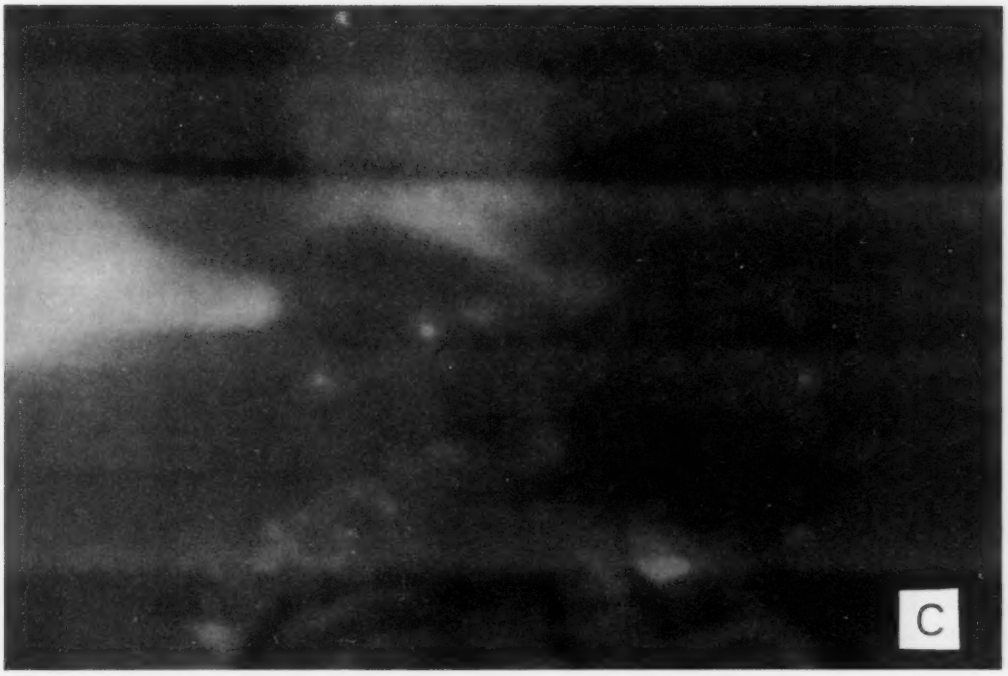
Figure 3.—Frames of (A) one dolphin (top right) approaching the posterior section of the codend (bottom), (B) dolphin (top) pushing the posterior section of the codend (bottom) forwards, and (C) two dolphins (side view - top left) feeding on small fish escaping from the codend. Because visibility was low and the frames were taken from video, picture quality is very poor.

act with the trawls (either at the surface or on the seabed), there is little indication that this behavior results in any mortality due to entanglement. For example, as part of a 3-year observer-based study to examine the by-catch of prawn trawlers in NSW (Liggins et al., 1996; Liggins and Kennelly, 1996; Kennelly et al., 1998), a total of 579 fishing trips were sampled with no record of any cetacean deaths. In addition, interviews and discussions with commercial fishermen have revealed that such deaths are apparently quite rare. These observations are supported by previous studies examining the interaction between bottlenose dolphins and commercial fishing operations (e.g. Corkeron et al., 1990).

While it is evident that dolphins regularly aggregate around trawling operations in NSW, the absence of any data describing the feeding behavior and composition of diets precludes any estimation of the extent or scale of any interactions. Nevertheless, assuming the potential for at least some interaction, the evidence presented here may have important implications for quantifying the selectivity of prawn trawls and estimating rates of by-catches from prawn trawlers. For example, it is evident that dolphins interacting with the trawl during fishing can cause significant changes in the fractional mesh openings in the codend resulting in alterations to the overall selectivity of the trawl (especially for prawns). More importantly, however, the scavenging and associated release of by-catch from the codend (either at the surface or on the seabed) represents one component of fishing-induced (F) mortality (see Chopin et al., 1996) that can not be easily estimated, but which nevertheless may contribute quite significantly to the overall fishing mortality of particular by-caught species (e.g. whiting). The potential for this type of bias has generally been ignored in studies that have quantified by-catches, since it is almost always assumed that the catch landed at the end of each tow represents the total catch caught and retained during fishing. Given the observations made in the present study, future research into gear performance, selectivity and quantification of by-catches may benefit from some assessment of the potential extent of such interactions.

One relatively inexpensive method of quantifying the extent of the interaction observed in the present study would be to conduct paired gear comparisons, using twin or tripled rigged trawls (Broadhurst and Kennelly, 1997) with a large-meshed, rigid cover or cage attached to one net so that it encompasses and extends beyond the posterior section of the codend to prevent dolphins from interacting with the main codend. The catch from this "modified" trawl

B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could then be compared to the normal commercially rigged "control" net. Assuming no differences in the fishing performances or selectivities of the two nets (due to the presence or absence of the cover), which in any case could be tested for, the differences in catch rates across replicate tows should provide an estimate of the component of by-catch released due to interactions by dolphins.

Commercial fishermen in NSW may also consider using similar sorts of modifications to the posterior sections of their codends (behind the composite square-mesh panel) on a regular basis to prevent dolphins from manipulating the codend and inadvertently releasing commercially important prawns and cephalopods. Figure 4 shows one possible modification, comprised of a panel of large, heavy mesh (e.g. 4 mm braided, mesh size 90 mm) sewn around the posterior section and extending for up to 1 m past the end of the codend, that may prevent physical contact by dolphins. Variations of this type of modification have been successfully used by fishermen for many years to prevent sharks from damaging the codend and catch during fishing, with no recorded deaths of cetaceans due to entanglement. Alternatively, it may be feasible to examine the utility of trawl-mounted, battery-operated acoustic deterrents, similar to those used to reduce the by-catch of dolphins in gillnet fisheries in the northeastern United States (Lien, 1995). Further research on a fishery-specific basis is needed, however, to assess the extent to which dolphins rely on food from trawls during fishing and, if any modifications to trawls to prevent removal of by-catch would negatively influence their abundances.

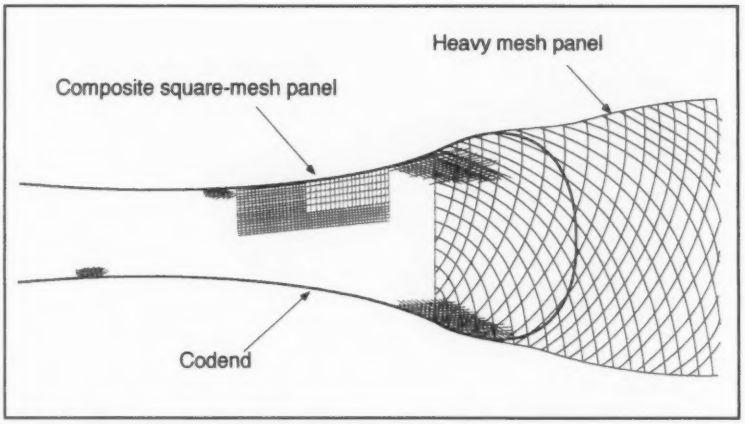

Figure 4.—Diagrammatic representation of proposed modification to posterior section of codends to prevent interaction of dolphins.

Acknowledgments

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Declining Rockfish Lengths in the Monterey Bay, California, Recreational Fishery, 1959–94

JANET E. MASON

Introduction

Marine recreational bottom fishing from commercial passenger fishing vessels (CPFV's), known as partyboats and charter boats, has been popular in the Monterey Bay area of central California since the late 1920's (Clark and Croker, 1933). Passengers pay a fee to be taken to one or more offshore fishing sites, where they fish while the boat drifts over bottoms from 9 to 274 m deep (Sullivan, 1995). The skipper locates concentrations of fish on the bottom or in midwater, and anglers catch an average of 11–12 fish per day (Karpov et al., 1995). For the purpose of this paper, the Monterey Bay area, approximately 100 km south of San Francisco, includes all sites normally fished by CPFV's from the ports of Santa Cruz, Moss Landing, and Monterey (Fig. 1) and extends from Año Nuevo, about 35 km north of Santa Cruz, to Point Sur, about 35 km south of Monterey. This area received 24% of CPFV effort and produced 43% of CPFV landings in northern California from 1981 to 1986 (Karpov et al., 1995). Most of the fish caught (85%) are of the genus *Sebastes*, commonly called rockfish (Miller and Geibel, 1973; Karpov et al., 1995).

Rockfish have dominated the catch from CPFV's in the Monterey Bay area from the 1950's to the present (Miller and Geibel, 1973; Karpov et al., 1995; Reilly et al.[1]; Wilson-Vandenberg et al.[2]). At least 29 species of rockfish appear in the CPFV catch (Miller and Geibel, 1973), but the fishery heavily targets the few aggregating species found in limited areas. Over 72% of the catch in 1960–86 (Mason, 1995) and 76% in 1987–91(Reilly et al.[1]) came from six aggregating species: bocaccio, *S. paucispinis*; chilipepper, *S. goodei*; blue rockfish, *S. mystinus*; yellowtail rockfish, *S. flavidus*; widow rockfish, *S. entomelas*; and olive rockfish, *S. serranoides*. Over the years the proportions of these species in the catch have changed from predominantly blue rockfish in the 1950's, to both blue and yellowtail rockfish in the 1960's (Miller and Geibel, 1973), to more chilipepper and bocaccio in the 1980's (Mason, 1995), and back to more blue rockfish in the 1990's (Wilson-Vandenberg et al.[2,3]; Wilson et al.[4]).

The continuous harvest of rockfish by the CPFV fishery has raised questions about the sustainability and health of this fishery. Some anglers and boat operators believe that rockfish are smaller

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ABSTRACT—California's Monterey Bay area is an important center of recreational fishing for rockfish of various Sebastes *species. The species composition of commercial passenger fishing vessel catches from 1959 to 1994 varied with changes in fishing location and depth. The shift from shallow nearshore locations to deeper offshore locations in the late 1970's and 1980's changed the emphasis from the blue rockfish,* S. mystinus, *of shallow waters to the deeper, commercially fished chilipepper,* S. goodei, *and bocaccio,* S. paucispinis. *The mean size of rockfish in the catch increased as the latter species were targeted at greater depths but then declined as stocks of older fish disappeared by the mid 1980's. During 1960–94 the mean size of all ten leading species in the recreational catch declined. The declines ranged from 1% for canary rockfish,* S. pinniger, *to 27% for chilipepper. The sizes of the deeper living species declined more than those of shallower species. The low frequency of strong recruitment events and increase in fishing mortality and natural mortality appear to have contributed to the declining mean size. The scarcity of older fish, observed as a drop in mean size to below the size of maturity for 50% of females, leads to concern for future recruitment of the larger species, especially bocaccio, chilipepper, yellowtail rockfish,* S. flavidus, *and canary rockfish.*

[1] Reilly, P. N., D. Wilson-Vandenberg, D. L. Watters, J. E. Hardwick, and D. Short. 1993. On board sampling of the rockfish and lingcod commercial passenger fishing vessel industry in northern and central California, May 1987 to December 1991. Calif. Dep. Fish Game, Mar. Res. Div. Admin. Rep. 93-4, 242 p.

[2] Wilson-Vandenberg, D., P. N. Reilly, and L. Halko. 1995. Onboard sampling of the rockfish and lingcod commercial passenger fishing vessel industry in northern and central California, January through December 1993. Calif. Dep. Fish Game, Mar. Res. Div. Admin. Rep. 95-2, 122 p.

[3] Wilson-Vandenberg, D., P. N. Reilly, and C. E. Wilson. 1996. Onboard sampling of the rockfish and lingcod commercial passenger fishing vessel industry in northern and central California, January through December 1994. Calif. Dep. Fish Game, Mar. Res. Div. Admin. Rep. 96-6, 96 p.

[4] Wilson, C. E., L. A. Halko, D. Wilson-Vandenberg, and P. N. Reilly. 1996. Onboard sampling of the rockfish and lingcod commercial passenger fishing vessel industry in northern and central California, 1992. Calif. Dep. Fish Game, Mar. Res. Div. Admin. Rep. 96-2, 103 p.

Figure 1.—Extent of the Monterey Bay CPFV fishing area on the central coast of California.

and less available than in the past, especially close to port. Reilly and coworkers[1] studied the species composition, mean length, and catch per angler hour in the fishery from 1987 to 1991. They found variation in the mean length of individual species and recommended a longer study to determine trends. In this paper, I combined 8 years of their studies with earlier data to provide a longer historical perspective on mean lengths of the ten dominant rockfish species over a 34-year period. These changes will be reviewed in light of the relative abundance of the species in the catch and the effect of new recruitment on mean length in the catch.

The relative importance of particular rockfish species has changed with their availability over the years and with the CPFV fleet's response. Blue rockfish dominated the catch in the first CPFV survey by the California Department of Fish and Game (CDFG) in 1959–60 (Miller and Gotshall, 1965). Miller and Gotshall expressed concern about the declining availability of blue rockfish which dropped that year from 54% to 18% of the local Santa Cruz catch. Blue rockfish aggregate in shallow water <70 m deep (Miller and Geibel, 1973). Like most rockfish species, they do not migrate and are therefore easily depleted in local areas. Miller and Geibel (1973) found that 95% of blue rockfish recaptured from tagging releases inside kelp beds were found at the release site over a 3-year period, and that 85% of recaptured adult blue rockfish from tagging outside kelp beds moved <1.6 km. Length distributions of the catch from fishing areas 15 km apart remained distinct over several years, confirming the isolation of local populations and the lack of replenishment by adults from other areas despite differences in fish density (Miller and Geibel, 1973).

As catches of blue rockfish declined near Santa Cruz in the 1960's, CPFV skippers maintained high catch rates through two strategies: fishing farther from port for blue rockfish or shifting to deeper water to target other species such as yellowtail rockfish (Miller and Geibel, 1973). Boats from Santa Cruz located concentrations of blue rockfish at Año Nuevo, 15 km from port, but after a few years even these distant stocks declined in mean length and in availability. In the area nearer port, yellowtail rockfish became the leading species in the catch, taken in midwater over banks from 66 to 100 m deep (Miller and Gotshall, 1965).

A second shift to fishing in even deeper water occurred by 1977 as chilipepper rockfish, caught near the bottom at depths averaging 116–135 m (Sullivan, 1995), became the dominant species (Mason, 1995). Bocaccio, greenspotted rockfish, *S. chlorostictus*, and greenstriped rockfish, *S. elongatus*, were also caught at these depths. These four species are used in this report as indicators of deepwater fishing (depths of 75 m or deeper). Bocaccio occur in shallow water as juveniles and in deep water as adults, and are considered mixed-depth species in some studies (Karpov et al., 1995). In the Monterey Bay area they are generally taken by CPFV's at 75 m and deeper (Thomas and Bence 1992; Sullivan, 1995; Reilly et al.[1]), and thus are deepwater species for this fishery.

The Monterey Bay area had the highest proportion of deepwater species in the total recreational catch of any area in northern and central California during 1981–86 (Karpov et al., 1995). The proximity of deepwater fishing sites along the Monterey Canyon and Carmel Canyon makes these species more available to CPFV's from Monterey Bay than from other ports. The percentage of CPFV trips to deepwater areas in Monterey Bay recorded by CDFG increased from 56% in 1987 to a maximum of 72% in 1990–91(Reilly et al.[1], Wilson-Vandenberg et al.[2,3]; Wilson et al.[4]). Deepwater trips dropped to 28% by 1994 as effort shifted back to blue rockfish in shallow water after 1992 (Wilson-Vandenberg et al.[2,3]).

The sport and commercial fisheries targeted different species until the 1970's, but as CPFV's moved into deeper water, that distinction disappeared. Chilipepper and bocaccio have dominated commercial rockfish landings in Monterey Bay for more than 100 years. Bocaccio and chilipepper together accounted for 70% of the landings from set lines in 1937–38; yellowtail rockfish, vermilion rockfish, *S. miniatus*, and canary rockfish, *S. pinniger*, totaled another 21% (Phillips, 1939). Bocaccio and chilipepper remained dominant despite changes in commercial fishing gear from set lines in the 1930's, to balloon trawls in the 1950's, to gillnets in the late 1980's (Heimann, 1963; Pearson and Ralston, 1990). From 1980 to 1994 chilipepper and bocaccio have dropped from 80% to 54% of the rockfish catch. The relative importance has shifted from mostly bocaccio before 1984 to mostly chilipepper after 1990. The commercial hook-and-line fishery has increased in both landings and proportion of the commercial catch since 1990 (Pearson and Almany, 1995). A nearshore hook-and-line fishery for live fish has developed throughout the state since 1989 (California Department of Fish and Game, 1998). As the CPFV fleet moved into deep water and the commercial fleet into shallow water, fisheries interactions increased.

Changes in the relative abundance of particular species of rockfish can be inferred from their proportion in the CPFV catch, but relative importance may be affected by trends in abundance of other target species, as well as changes in fishing locations. Another

indicator of the condition of the fishery may be the size of fish caught. The annual mean length of the total CPFV rockfish catch reflects the average size of all species combined, and a drop in this mean may indicate either an increased proportion of smaller species in the catch or a decreased size of the dominant species. It is necessary to look at both the size of individual species and their changing proportions in the catch to evaluate changes in overall size.

A decline in the mean length of a fished species is often considered an indicator of increased fishing mortality. A large proportion of the biomass for unexploited rockfish populations consists of older, larger, slower growing fish (Leaman and Beamish, 1984). Increased fishing pressure removes these older fish more rapidly than they are replaced, so if recruitment and growth are stable, higher fishing mortality will reduce the mean length. In rockfish populations, however, recruitment varies from year to year, and the size distribution of young fish varies with the presence or absence of successful year classes. A strong year class can dominate the catch as it recruits to the fishery, first reducing and then increasing the mean length as the year class grows. If another strong year class recruits to the fishery, the mean length may drop again.

I examined the CPFV fisheries from Monterey Bay for: 1) changes in fishing effort and success, 2) changes in relative importance of species from different depths, 3) changes in the size of the ten leading species, 4) the mean length caught relative to size at maturity, 5) the effects of new recruitment on the mean length of these species, and 6) similar trends in the mean length of species from CPFV and commercial landings.

Methods

Total catch of rockfish was taken from annual summaries of the logbooks submitted by CPFV skippers to the California Department of Fish and Game. Individual rockfish species are not recorded in the logbooks, so I estimated the annual catch by species by multiplying the total rockfish caught by the annual proportion of each species derived from the sampling programs. The total number of anglers is also recorded in the CPFV logbooks, and since all trips out of the Monterey Bay area are day trips, the number of anglers represents angler days. The years covered by the various sampling programs are displayed in Figure 2.

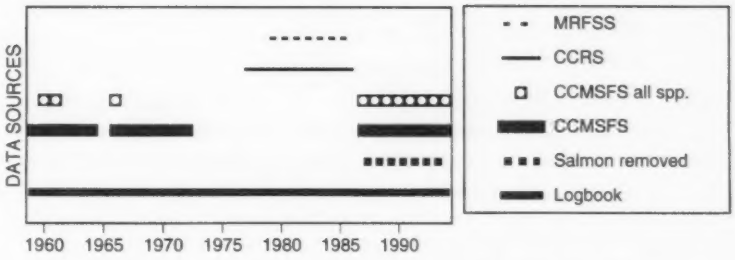

Figure 2.—Sources of data. Logbook data provide total CPFV catch and effort; salmon removed indicates years salmon effort was subtracted from the logbook total to calculate catch and effort for just rockfish trips. Surveys measuring species composition and length frequency in various years include: CCMSFS — Central California Marine Sport Fishing Survey, years when only blue rockfish were measured; CCMSFS all spp., years when all species were measured; CCRS — California Cooperative Rockfish Survey; and MRFSS — Marine Recreational Finfish Statistical Survey.

Catch per angler day (CPAD) was calculated in two ways. Simple CPAD was calculated from the total catch divided by the total anglers. This included all types of CPFV fishing in the Monterey Bay area. CPAD from rockfish trips was what remained after the effort and catch from trips targeting Pacific salmon, *Oncorhynchus* spp., were removed from the total trips. For most of the time series, the effect of salmon trips on CPAD is negligible, but CPFV logbooks indicate more salmon have been caught since 1986. Boats trolling for salmon catch very few rockfish. From 1987 to 1994 CDFG examined the logbook records for each fishing trip and removed salmon trips (CPFV trips that caught salmon and averaged less than 4 fish per angler) from the calculation of rockfishing effort (Reilly et al.[1]; Wilson-Vandenberg et al.[2,3]; Wilson et al.[4]). Data were not available to make this correction for previous years.

The CDFG also compared the number of anglers and fish reported in logbooks for observed trips with the actual numbers observed by CDFG samplers to determine the unreported catch and effort for 1987–94. Adjusted total rockfish and rockfish effort were calculated from these rates. The CDFG also categorized the trips by fishing depth during this period (Reilly et al.[1]; Wilson-Vandenberg et al.[2,3]; Wilson et al.[4]).

Data on species composition and length frequency were gathered from several sampling programs spanning a 34-year period in the Monterey Bay area (Fig. 2). The earliest data are from the Central California Marine Sport Fish Survey (Miller and Gotshall, 1965; Miller and Geibel, 1973). Species composition and lengths of blue rockfish were recorded each year from 1959 to 1972 except for 1965. Lengths of all rockfish species were sampled from CPFV's only in 1960, 1961, and 1966. The California Cooperative Rockfish Survey collected species composition and length information from CPFV's for 1977–86 for Santa Cruz and Monterey and for 1979–81 for Moss Landing (all Moss Landing CPFV's had moved to Monterey by 1982). The creel census portion of the Marine Recreational Fishery Statistics Survey collected data on species composition and length for 1979–86 for Santa Cruz County and Monterey County ports and overlaps with the previous survey (Holliday, 1984). These data augment reduced sampling by the California Cooperative Rockfish Survey during these years. Data sources through 1986 and numbers of fish sampled are further described by Mason (1995). The Central California

Marine Sport Fish Project again collected samples from 1987 to 1994, and their sampling techniques are described by Reilly et al.[1] In 1990, samples were taken only from January to June, and in 1991 from August to December so these 2 partial years were combined to remove the seasonal differences in species composition.

All sampling programs measured total length of rockfish in millimeters. Frequency distributions were calculated in 0.5 cm length intervals (e.g. 10.0 to 10.4 cm) and grouped to 2 cm for display and labeled by lower limit of interval. Mean lengths for species were calculated from the total lengths for years with at least 20 measured fish of a species. The 10 leading species were used for analysis of mean length because they had nearly complete series. Boundaries for the 10th and 90th percentiles were calculated from 0.5 cm length-frequency categories and used to indicate the size range. Mean lengths were compared to the sizes at which 50% of the females and 50% of the males reach sexual maturity, as described by Wyllie Echeverria (1987) for northern California rockfish.

Length frequencies were expanded by catch by multiplying the total catch of rockfish reported in the CPFV logbooks times that species' proportion in the sampled catch times the proportion in each 2 cm size class. Length frequencies for four species with at least 50 fish per year were used to produce the length-frequency time series.

Only the California Cooperative Rockfish Survey (1977–86) identified the sex of rockfish when collecting lengths from the CPFV's. These lengths were used to examine sexual dimorphism in length frequency for each sex for each of the ten leading species.

Estimated weights of rockfish landed by CPFV's were derived from the estimated annual catch by species to compare CPFV and commercial landings. I calculated weights from the length frequencies by using length-weight parameters calculated from studies in southern California (Love et al., 1990), except for blue rockfish which Miller and Geibel (1973) studied in the Monterey Bay area. I divided the estimated CPFV species landings by the sum of CPFV landings and expanded commercial landings from the California port sampling program data (Pearson and Ralston, 1990; Pearson and Almany, 1995) to get the percent caught by CPFV's. Logbooks may underestimate the CPFV catch by the proportion of fishing trips that are not reported, so percentages are adjusted to include unreported catch. I also calculated mean lengths of species by commercial gear type from this sampling program for principal species occurring in both the CPFV and commercial fisheries. Total commercial rockfish landings were obtained from the series of annual commercial landings published by the California Department of Fish and Game (1980–95).

Results

Many aspects of the CPFV fishery have changed during the 35 years covered by this report. There have been increases and decreases in effort and in total catch, as well as changes in the species caught and the depths fished. Declines in the proportion of certain species in the catch may reflect reduced availability of these species or increased availability of alternate species. The catch of smaller fish indicates a scarcity of large fish of particular species available to this fishery. All of these changes must be examined in relation to each other to evaluate the condition of the fishery.

Catch and Effort

Total catch by CPFV's increased threefold from 1964 to 1982 (Fig. 3a). Rockfish ranged from 81% to 95% of the catch and averaged 91% from 1959 to 1994. The rise in catch closely reflects the increased fishing effort through 1982 (Fig. 3b). Effort dropped sharply from 1983 to 1985 and catch dropped in 1984–85. As effort dropped in 1983, CPAD peaked (Fig. 3c) but decreased the next year as catch also dropped. Total effort climbed to a second peak in 1988, but total catch did not increase proportionately (Fig. 3a), probably because more effort was directed toward Pacific salmon which became more available after 1985.

When salmon become available, many boats troll for them instead of bottom fishing for rockfish. Salmon availability increased in the local area, and their catch rose from 2,500 (1.0% of CPFV catch) in 1985 to about 10,000 salmon (2.8% of CPFV catch) in 1986 (shown at 10 times actual catch in Fig. 3a). From 1987 to 1994, salmon fishing accounted for an average of 26% of the CPFV effort and a maximum of 34% in the combined 1990–91 seasons.

Catch per angler day differs for trips bottom fishing for rockfish and trips trolling for salmon. Marine anglers in California may keep 20 fish per day, 15 may be one or more species of rockfish, but only two may be salmon. The average catch of rockfish has varied from 8 to 13 fish per angler day (Fig. 3c). Catch per angler day for salmon trips averaged less than 4 fish per angler day. What appears to be a declining trend in catch per angler day after 1982 (Mason, 1995) was calculated from total fish divided by total anglers. When salmon fishing trips are removed after 1986, CPAD for rockfish trips stays at 10–12 fish per day. Salmon effort was negligible in earlier years, except for 1959–62, 1964, 1967, and 1986 when salmon totaled 1% or more of the CPFV catch. The low rockfish CPAD in 1985 reflects both a slight increase in salmon effort and low availability of rockfish.

Total catch and effort for the Monterey Bay area may have declined less than the logbooks indicate. Although skippers are required to report the number of trips along with the number of passengers and the number of fish caught, not all trips are actually reported. Skippers reported 73% of both the actual number of anglers and the fish caught on trips observed by CDFG in the area from 1987 to 1991 (Table 76 in Reilly et al.[1]) and only 58% of the number of anglers and 56% of the catch for 1992–94. The percentage of trips reported dropped from a peak of 87% in 1988 to a low of 48% in 1994. The catch reported has also dropped for those years (from 73% to 84%: Wilson-Vandenberg et al.[2,3]; Wilson et al.[4]). Adjusted total catch and rockfish effort are indicated only after 1986 (Fig. 3, a

and b), since we do not have compliance data for earlier years. Thus the decline in total catch and effort in 1993–94 may be slightly exaggerated by under reporting.

Species Composition

Catch composition has changed over time with changes in the depth and habitat fished. Blue rockfish was the leading species taken in the late 1950's. From 1959 through 1972 blue rockfish and yellowtail rockfish dominated, averaging 35% and 21% of the catch, respectively (Fig. 4). Olive rockfish averaged 6% of the catch and other shallow-water species together averaged only 3% through 1972. Since 1977, four species caught in deeper water (below 75 m) have become very important to the fishery averaging 32% of the catch in 1977–94 as compared to 7% in 1959–72. Most important in this group is chilipepper, which increased from 2% of the catch in 1959–72, to 15% in 1977–85, and 21% in 1986–94. The three other members of the deepwater group (bocaccio, greenspotted rockfish, and greenstriped rockfish) also increased in relative importance after 1977, although from 1991 to 1994 they declined sharply from 38% to 17% of the catch. Species compositions for 1990–91 are averaged from two incomplete sampling years (see Methods).

The relative importance of the different species groups varied more after the expansion into deeper water in 1977 than in earlier years. The fleet did not shift completely away from shallow water, but moved among different fishing areas at different depths, thus targeting a greater variety of species. The most blue rockfish were landed by CPFV's (estimated at 290,000) in 1981 after the fishery diversified into deep water. High fishing effort and good availability of species from all depth ranges contributed to the record total landings in 1981–82 (Fig. 3a). The catch included chilipepper, bocaccio, and widow rockfish from deep water, yellowtail rockfish from intermediate depths, and blue rockfish from shallow water. After 1978, total catch peaked only in years when blue rockfish were available, such as in 1988 and 1993. The proportion of the catch comprising the four deepwater species has steadily declined since 1986 (Fig. 4) despite increased deepwater trips in 1989–92 (Table 1). The proportion of trips to deep water did not decline appreciably until 1993–94. The ten leading rockfish species are listed by order of abundance in the annual landings for the entire time period in Table 2.

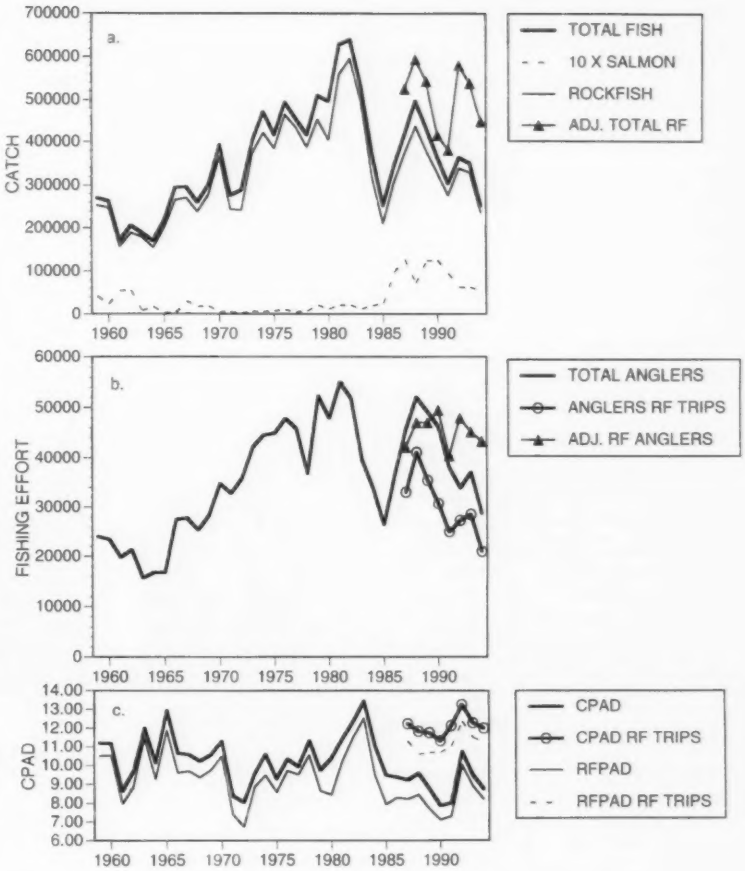

Figure 3a.—Catch from Monterey Bay area CPFV's: TOTAL FISH =Total fish reported; 10 X SALMON = salmon plotted at 10 times reported numbers; ROCKFISH = total rockfish reported; ADJ. TOTAL RF = total rockfish adjusted upwards for percentage not reported in logbooks. 3b.—CPFV effort in Monterey Bay area: TOTAL ANGLERS = total anglers reported; ANGLERS RF TRIPS = anglers from trips targeting rockfish (not salmon trips); ADJ. RF ANGLERS = anglers from rockfish trips adjusted upwards for percentage not reported in logbooks. 3c.—CPFV catch per angler day: CPAD = all fish from all trips; CPAD RF TRIPS = all fish from trips targeting rockfish; RFPAD = rockfish per angler day, all trips; RFPAD RF TRIPS = rockfish per angler day from trips targeting rockfish.

Sexual Dimorphism

Sexual dimorphism in total body length was present in some but not all species of rockfish sampled from 1977 to 1984 (Fig. 5). Sexual dimorphism was pronounced in blue rockfish: only 7% of the males were larger than the mean length of females. Only 4% of chilipepper males were 40 cm or larger

Table 1.—Percentage of CPFV trips to two depth ranges. Trips classified as mixed depth could not be separated into just one depth range.

Year	Trips (%)		
	Shallow (<80 m)	Deep (>80 m)	Mixed depths
1987	17	56	27
1988	22	56	21
1989	19	63	17
1990–91	19	72	9
1992	20	64	16
1993	7	40	53
1994	31	33	36

Table 2.—Rating and percentage contribution of the ten most abundant species in the CPFV catch from 1959–94.

Rank	Common name	Scientific name	Percent contributed
1.	Blue rockfish	*S. mystinus*	27
2.	Yellowtail rockfish	*S. flavidus*	16
3.	Chilipepper	*S. goodei*	11
4.	Bocaccio	*S. paucispinis*	7
5.	Widow rockfish	*S. entomelas*	5
6.	Olive rockfish	*S. serranoides*	5
7.	Rosy rockfish	*S. rosaceus*	3
8.	Greenspotted rockfish	*S. chlorostictus*	3
9.	Canary rockfish	*S. pinniger*	3
10.	Greenstriped rockfish	*S. elongatus*	2
Total contribution of top ten species			82

compared to 52% of females. Only 8% of male olive rockfish were larger than the mean length of females. Only 4% of male greenstriped rockfish were larger than the mean length of females. In all four of these species, the females attained a larger maximum length and a larger mean length than the males.

Some species (bocaccio, widow rockfish, and yellowtail rockfish: Pearson and Ralston, 1990) that are sexually dimorphic at larger sizes were less clearly dimorphic in the sizes taken by the CPFV fishery. The mean length of females was only slightly larger than that of males, but in each of these species females predominated in the largest size classes. Yellowtail rockfish males appeared to have a narrower size distribution than females, but since some sampled fish, especially immature ones, were not categorized by sex, the apparent lack of smaller males may result from a difficulty in identifying immature males. Canary rockfish and rosy rockfish did not display sexual dimorphism in the lengths taken from CPFV's, although Boehlert and Kappenmann (1980) found that canary rockfish females caught by research trawls had a larger mean length, and Pearson and Ralston (1990) found that canary rockfish females were more abundant than males in the larger size range from commercial trawls (>56 cm, a size not occurring in the CPFV samples). The mean length of greenspotted rockfish males was slightly larger than the mean length of females, and this is the only species in which males averaged larger than females. Greenspotted rockfish and rosy rockfish are not dimorphic in length, according to Lenarz and Wyllie Echeverria (1991).

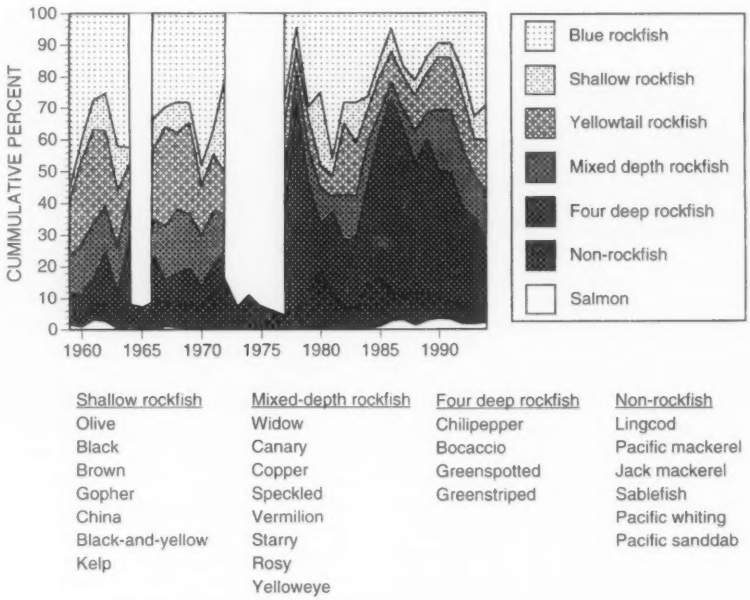

Figure 4.—Cumulative percentage of CPFV-caught rockfish by dominant single species (blue rockfish and yellowtail rockfish) and species groups based on depth. Blank areas are years without sampling of rockfish species.

Lengths

The mean lengths of the ten most abundant rockfish species caught on CPFV's in Monterey Bay between 1960 and 1994 are presented in Fig. 6. The spread between the 10th and 90th percentiles of lengths represents the size range of 80% of the catch. Plots of length frequencies (Fig. 7) display changes in lengths for four species.

The time series of blue rockfish lengths is the most complete because only blue rockfish were sampled throughout the 1960's (Fig. 6). The sharp drops in mean length and the 10th percentile of length in 1962, 1964, and 1968 reflect small fish recruiting to the fishery. Increasing mean length from 1970 to 1972 can be attributed to the growth of the new recruits observed in 1968 (Fig. 7). Mean length was greatest during the period of highest catches (1977–84). Length frequencies indicate a mode of larger fish at about 34 cm as well as a mode of smaller fish at 26–28 cm visible in 1981; this bimodality could be produced by two or more rela-

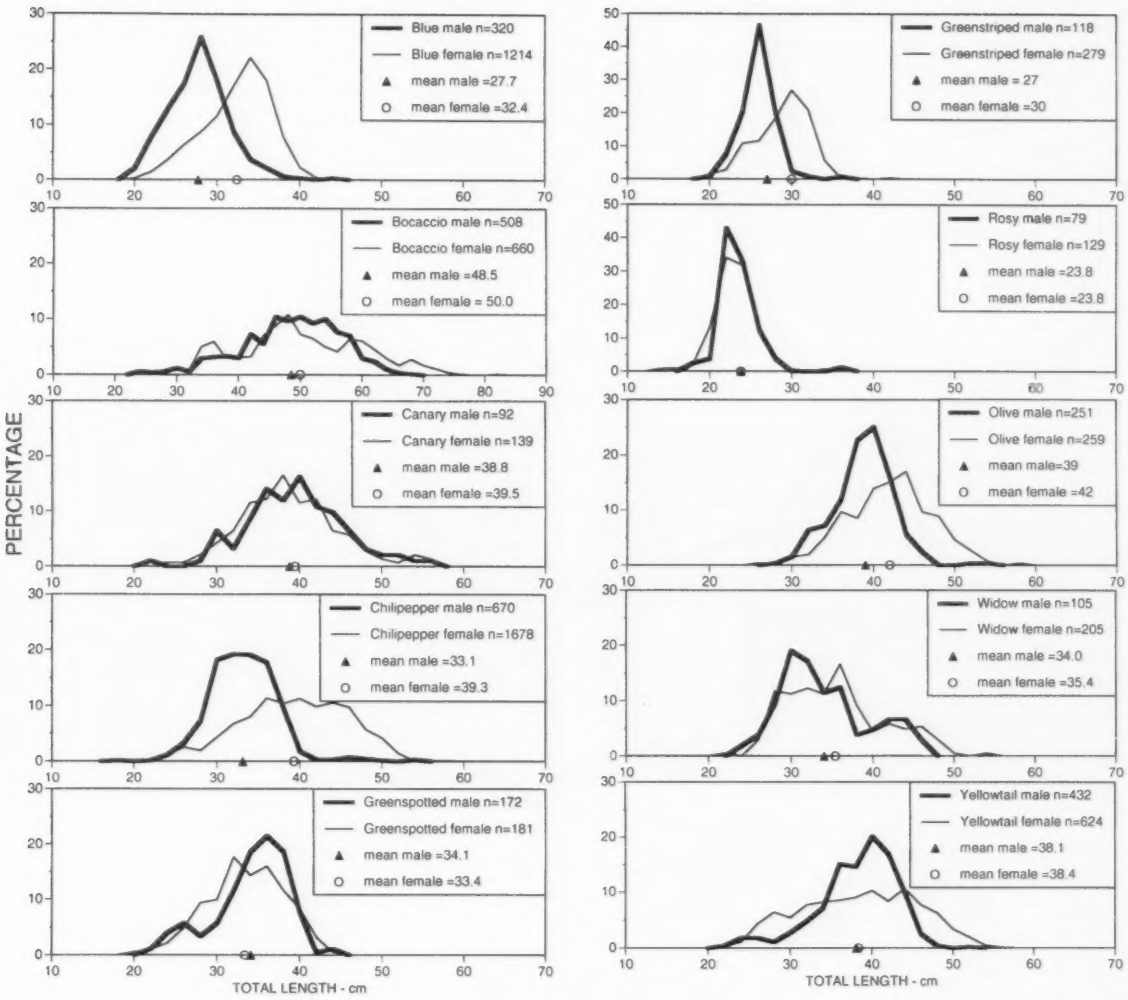

Figure 5.—Sexual dimorphism in length distributions of ten leading rockfish species caught by CPFV's in Monterey Bay in 1977–86 (California Cooperative Rockfish Survey data); each 2 cm group is shown as a fraction of total males or total females (n = number sampled per sex).

tively strong year classes separated by less strong year classes, but also reflects the pronounced sexual dimorphism of this species. Mean length dropped in 1984 as larger fish became less abundant in the catch; after that only 42% of the catch was larger than the size (29 cm) at which half of blue rockfish females mature (Wyllie Echeverria, 1987). In 1977–84, 79% of the fish sampled were female. It is not known if the smaller mean length after that reflects more males in the catch or smaller females, but few fish have reached the large sizes present in 1977–83.

Yellowtail rockfish were largest in 1977, 1983, and 1991 (Fig. 6). New recruitment to the fishery appeared as a drop in the length of the 10th percentile in 1978, 1984, and 1987. Growth of these recruits can be tracked in the mean length and in the length frequencies of the catch for the next four years (Fig. 7). Since 1985, large fish have been scarce and only 32% of the yellowtail rockfish have been above the length (36 cm) at which half of the females reach maturity, compared to 54% from 1977–84. The drop in 1994 to the lowest size for both the mean length and length of the 10th percentile may indicate new recruitment to the fishery, especially since yellowtail rockfish contributed a significant proportion (15%) of the CPFV catch in that year, but also reflects the smaller size of fish caught in

shallow water. Half of the yellowtail rockfish were caught in shallow water in 1994 as compared to 10% in earlier years (Reilly et al.[1]; Wilson-Vandenberg et al.[3]).

Chilipepper had the most dramatic and sustained decline in mean length of the catch, 14 cm from 1960 to 1994 (Fig. 6). The increasing mean length during 1980–82 resembled growth of recruits but was faster than the growth rates of either males or females described by Wilkins (1980) or Rogers and Bence.[5] This increase in mean length may indicate several older year classes exploited by an expanding fishery rather than growth of a single year class. The drops in the 10th percentile of length in 1986 and in mean length and 90th percentile in 1987 indicate a surge of new recruits, which can easily be seen in the length frequencies (Fig. 7). Catches of chilipepper soared in 1987 with a strong single mode of fish that remained dominant for the next 2 years. The growth rate in this period is consistent with growth rates for females described by Wilkins (1980) and Rogers and Bence.[5] By 1989, the peak broadened as male growth slowed, but by 1990 this mode's contribution had greatly declined and catches of chilipepper decreased. After 1984 there was a noticeable lack of larger fish; only 48% were 34 cm or larger (the size of maturity for half of the females) when compared to 74% during 1977–84. The proportion of females in the catch after 1986 is not known, but during 1977–86, 71% of the identified fish were female. Since 1992, the mean length has been below the length at maturity (34 cm) for 50% of females (Fig. 6). Although this drop may be caused by recruitment, the number of chilipepper in the catch has continued to decline, indicating that recruitment was only moderate.

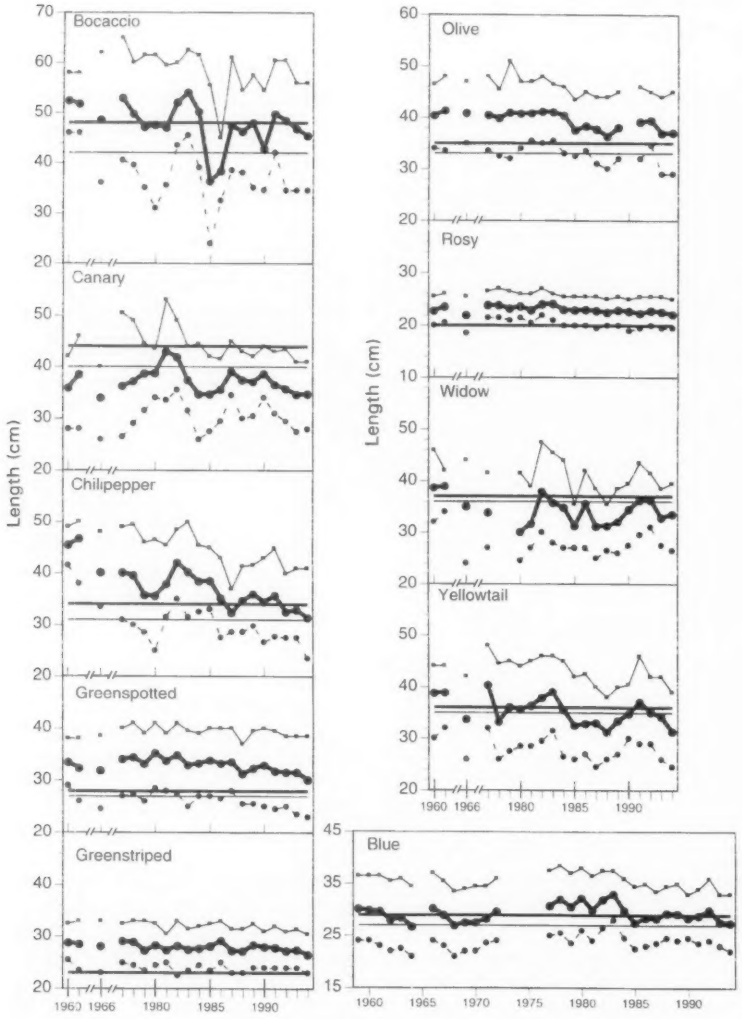

Figure 6.—Changes in length over time for ten leading species of rockfish: mean length, heavy line; 10th percentile, dashes; 90th percentile, light line. Breaks in lines indicate missing or insufficient data. Data are discontinuous for all species except blue rockfish in 1962–65 and 1967–76. Size at maturity for 50% of species is indicated by horizontal lines: female = heavy line; male (if different from female) = light line.

Bocaccio had the largest mean length and 90th percentile of the ten leading species and also the greatest fluctuation in mean length in the catch. The mean length of bocaccio dropped dramatically from its largest mean in 1983 to its smallest just 2 years later. This drop in mean length and in the 10th percentile in 1985 reflected new recruitment to the fishery, and these new recruits dominated the bocaccio catch for the next 4 years (Fig. 7). Noticeable recruitment to the fishery also occurred in 1979, 1981, and 1990. Fish larger than the size of maturity of 50% of females (48 cm) have constituted 41% of the bocaccio catch since 1984, but before that they contributed 65%. Mean length has been below the size of maturity of 50% of females but above the length at

[5]Rogers, J. B., and J. R. Bence. 1992. Review of the fishery and auxiliary data for chilipepper rockfish in the Conception/Monterey/Eureka INPFC areas: a qualitative assessment of the status of the stock in 1992. *In* Appendices to the status of Pacific groundfish fishery through 1992 and recommended acceptable biological catches for 1993: Stock assessment and fishery evaluation. Pac. Fish. Manage. Counc., Portland, Oreg. 18 p.

maturity of 50% of males in all but 2 years since 1987 (Fig. 6).

The longest mean lengths for widow rockfish were recorded in 1960–61 and 1982 (Fig. 6). In 1982 an increased catch of large widow rockfish raised the length of the 90th percentile and contributed more to the increase in mean length than did the growth of smaller fish. Fewer than 20 widow rockfish were measured per year in 1978–79, so these years (when widow rockfish constituted less than 1% of the catch) are not included in the graph. The drop in the mean length and in the 10th percentile in 1987, followed by increasing mean length through 1992, indicate a pulse of recruitment to the fishery. Widow rockfish reached their highest percentage in the catch in 1988, as these new recruits were targeted. The return to smaller fish in 1993–94 may indicate new recruitment. More than half of the widow rockfish caught by CPFV's are juveniles; the mean length has been at or below the length at maturity for 50% of females (37 cm) and males (36 cm) since 1983.

The mean length of olive rockfish remained constant at about 40 cm from 1977 to 1984, but then it declined (Fig. 6). New recruitment to the fishery was apparent in 1988, followed by an increase in mean length to 1992. The drop in the 10th percentile of length in 1993–94 reflects recruitment of small fish. The percentage of olive rockfish in the catch is generally less than 5%, but it jumped to 18% in 1980 and to 9% in 1983. These increases in catch did not coincide with pulses of new recruitment as they did for bocaccio and chilipepper. The mean length has remained above the length of maturity (35 cm) for 50% of females throughout the period examined.

Rosy rockfish had the smallest mean length of the ten most abundant species (Fig. 6). Mean length of rosy rockfish varied little, but it dropped 1 cm from 1982 to 1983 and then gradually declined to 1994. The 10th percentile of length also declined by 2 cm and may have been affected by the discard of small fish. Rosy rockfish are not targeted by the fishery but are a smaller species caught incidentally to other species. Small fish are sometimes thrown back as "too small" even though expansion of their air bladder from rapid decompression causes them to float and die. The percentage of rosy rockfish retained (not discarded) in 1987–91 does not have an obvious trend but has varied between 84% and 93% in the Monterey Bay area (Reilly et al.[1]; Wilson-Vandenberg et al.[2,3]; Wilson et al.[4]). Earlier discard rates might have been higher. Almost all of the rosy rockfish sampled were above the length at maturity (20 cm) for 50% of the females throughout the time series.

Greenspotted rockfish mean length was larger in 1977–83 than in 1960, and it declined after 1987 to its lowest size in 1994. There are no apparent periods of recruitment and growth. The 10th percentile of length has declined despite the high retention rate of this species (97–99% in 1987–94). In all years, the mean length was above the length at maturity (28 cm) for 50% of the females.

Canary rockfish mean length varied over the study period and was largest in 1981–82. Periods of recruitment to the fishery in 1977 and 1984 are indicated by sharp 1-year declines followed by sustained increases in the 10th percentile and mean length. The most recent drop in mean length has been continuous since 1990. Canary rockfish mean length has been below the length at maturity of 50% of females throughout the study, and since 1983, 90% of the canary rockfish caught in the CPFV

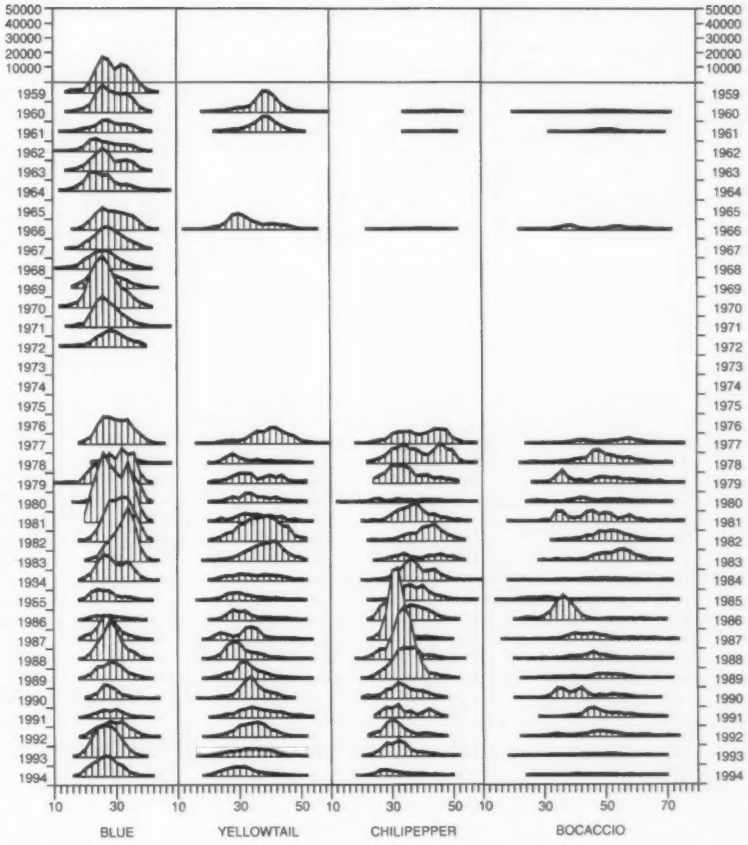

Figure 7.—Estimated annual CPFV catch for four leading species of rockfish by 2 cm length-frequency categories, 1959 at top to 1994 at bottom. The vertical scale at top displays the number of fish indicated by the height within each curve.

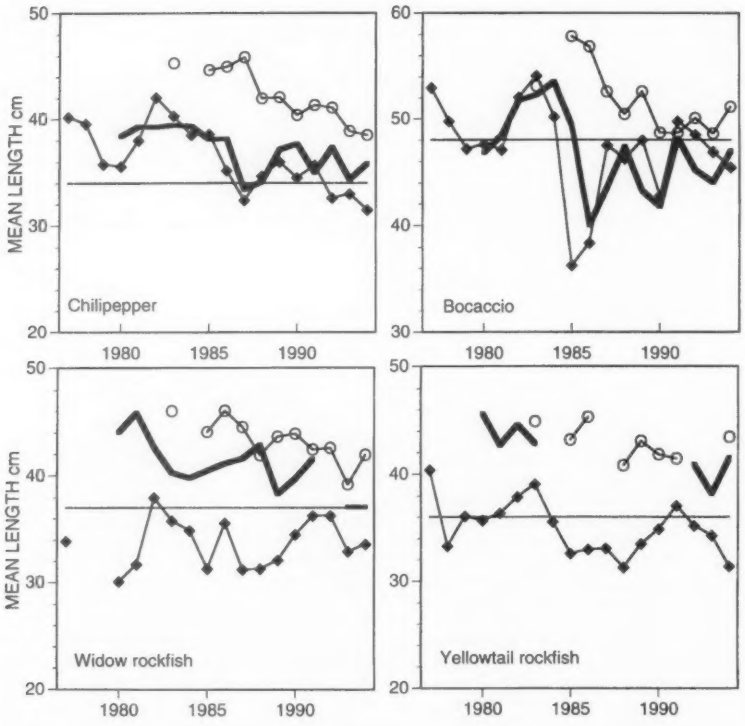

Figure 8.—Mean lengths of four rockfish species from two commercial fishing gears compared to means from CPFV. Heavy line represents mean from bottom trawls; circles represent mean from gillnets; diamonds represent means from CPFV's. Horizontal lines are as described in Figure 6.

fishery have been juveniles, below the length at maturity of 50% of females (44 cm) and 50% of males (40 cm).

The mean length of greenstriped rockfish fluctuated only slightly over the study period. The species is caught incidentally to targeted deepwater species such as chilipepper and bocaccio, and the mean length was the second smallest of the ten most abundant species in the catch. The mean length has declined steadily from 1989 to 1994. Despite their relatively small size, most of the greenstriped rockfish were retained: 96% in 1987–91(Reilly et al.[1]) and 93% in 1994 (Wilson-Vandenberg et al.[3]). Over 90% of them were larger than the length at maturity for 50% of females and males (both 23 cm).

There has been a net decline in the mean length of all ten dominant species between 1960 and 1994 (Table 3). The decline occurred after 1977 for all but two of the species. Eight of the ten species dropped at least 4% in mean length during this period. Chilipepper, bocaccio, widow rockfish, and yellowtail rockfish declined the most, dropping more than 10% in mean length from 1960 to 1994.

Mean Lengths From Commercial Fisheries

The declining mean length trends of chilipepper and bocaccio from the CPFV fishery were also present in the catch from the commercial trawl and gillnet fisheries (Fig. 8). The new recruitment evident in the CPFV fishery in 1985–87 can also be identified by a drop in mean length in the trawl and the gillnet fisheries. Gillnet mesh size selects larger fish which explains the larger mean length caught by this fishery and the delay in recruitment until fish reach gear-selected size. The decline in mean length of chilipepper rockfish was more gradual in the trawl fishery, where escapement related to mesh size or processor preference may limit the minimum size, than in the CPFV or gillnet fisheries.

The mean lengths of widow and yellowtail rockfish from CPFV's were noticeably smaller than the means from trawls and gillnets and may reflect escapement of smaller fish and the ontogenetic movement of older fish to deeper water (Love et al., 1990). Yellowtail rockfish are not targeted by trawlers in Monterey Bay and contribute only 5%, on average, of the commercial rockfish catch, so data are less complete. Mean lengths for commercially caught widow and yellowtail rockfish declined over time, coming closer to the mean lengths from CPFV's.

Table 3.—Percentage of change in total length for top ten rockfish species from CPFV's over two time periods. Negative numbers indicate declining size.

Species	Percent change 1960–77	Percent change 1960–94
Blue rockfish	3.01	–6.84
Yellowtail rockfish	4.12	–12.07
Chilipepper	–11.65	–27.31
Bocaccio	0.95	–12.28
Widow rockfish	–12.40	–11.35
Olive rockfish	0.25	–8.91
Rosy rockfish	4.82	–1.93
Greenspotted rockfish	1.79	–4.12
Canary rockfish	1.11	–1.35
Greenstriped rockfish	1.04	–4.28

Grouped Species Lengths

Grouping rockfish species together in different ways can reveal the larger trends in the fishery. The mean length of all rockfish caught on CPFV's was 3 cm (8%) larger in 1977 than in 1960–61, but varied before dropping sharply in 1994 to 10% below the 1960–61 mean (Fig. 9).

Comparing the relative contribution of larger and smaller species to the fishery reveals periods in which shifting proportions of these two groups affected mean length. Two size categories of species were created based on average mean length from 1960–94. As expected, the five species with average mean lengths of 35 cm or larger (bocaccio, chilipepper, canary rockfish, olive rockfish, and yellowtail rockfish) in-

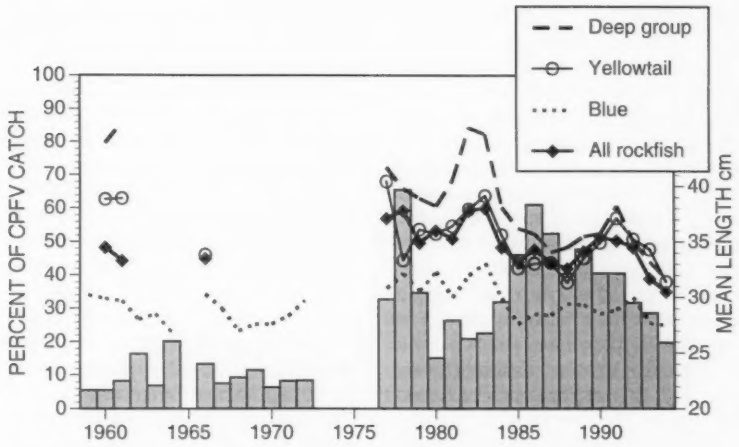

Figure 9.—Proportion of the four deep-water rockfish species (bocaccio, chilipepper, greenspotted rockfish, and greenstriped rockfish) in the total CPFV catch indicated by columns, scale on left. Mean length indicated by scale on right: dashes = group of four deep-water rockfish species, circles = yellowtail rockfish, dotted line =blue rockfish, and line with diamonds = total rockfish.

creased in the catch from 41% in 1959–72 to 48% in 1977–85, when mean length of total rockfish was high. As large species continued to increase in importance (to 53% of the catch in the 1985–94 period), however, the mean length of total rockfish dropped. The proportion of large species remained high until the proportion of blue rockfish increased (in 1993–94), at which point the mean length dropped even more. The mean length decreased from 1983 to 1992 despite an increased proportion of large species.

Grouping the species together by fishing depths reveals the influence of deepwater species on the overall mean length (Fig. 9). In 1960, when blue rockfish and yellowtail rockfish contributed about 60% of the catch, the mean length fell between the means of these two species. As the catch shifted to deepwater species by 1977, the mean length increased. Four key species (bocaccio, chilipepper, greenstriped rockfish, and greenspotted rockfish) caught in deeper water increased from 7% to 32% of the catch between 1972 and 1977. The mean length of the deepwater group was over 40 cm (11 cm larger than the mean length of blue rockfish in 1977).

The mean length for all combined rockfish was bounded by the means of the deepwater group and blue rockfish from 1977 to 1987 (Fig. 9). Deepwater species decreased in mean length from 1977 to 1980, as young bocaccio and chilipepper recruited to the fishery, but then increased in length to a maximum in 1982–83. Bocaccio contributed significantly from 1981 to 1983 and their larger size during this period is reflected in the longest mean length for total rockfish. Blue rockfish were also at their largest size from 1977 to 1983 and contributed to higher total means. The mean lengths of all the important groups decreased in 1984–85 with a scarcity of large fish, and remained low through 1987. Despite the increased proportion of deepwater species (columns in Fig. 9), the overall mean length was reduced in this period by the smaller size of the dominant species.

Both yellowtail rockfish and the deepwater species group increased in size in 1989–91 with the growth of young fish, and their high proportion in the catch kept the mean length of all combined rockfish close to that of the deepwater group. The length of the deepwater species group declined after 1991 with the reduced proportion of bocaccio and declining size of chilipepper, greenspotted rockfish, and greenstriped rockfish; yellowtail rockfish size also declined. The difference in size between the deepwater group and blue rockfish shrank from 10 cm in 1991 to only 5 cm by 1994. The mean length for all combined rockfish reached its lowest recorded level in 1994 as smaller blue rockfish contributed more to the catch. The smaller size of the deepwater species has noticeably affected the overall mean length.

Discussion

Reduction of the mean length of fish caught by a fishery is often used as an indicator of increased mortality rate. In the Monterey Bay area CPFV fishery, the mean length of rockfish has declined; however, the interpretation of this trend is complicated by the changes in species composition of the fishery. The decline in size results from a decline in the mean length of the dominant species as well as from shifts in the relative contribution of various species to the catch. Several factors which vary over time contribute to the declining overall size of rockfish caught by CPFV's: 1) changes in target species, 2) removal of larger fish by both CPFV's and commercial fisheries, 3) environmental effects on mortality and recruitment, and 4) declining proportion of spawning adults.

The change in target species from shallow-water species to deepwater species in 1977–78 increased the mean length of combined rockfish in the catch. Large chilipepper and bocaccio were available in these deeper areas through 1983, but a shift back to shallow-water fishing for blue rockfish in 1979–84 moderated the mean length (Fig. 9). The return to deepwater fishing in 1985–89 did not increase the overall mean length, because the size of fish in the deepwater group had dropped. Although the mean length of the group of deepwater species was larger than that of the shallow-water species (blue rockfish), the periods after 1977 with higher proportions of deepwater species did not correspond with the largest mean lengths for total rockfish. Changes in target species explain only the 1977–81 changes in total mean length.

Variability in the size of dominant species affected the overall mean length

more than species composition after 1981. One component of that mean length is the proportion of large fish in the catch. The mean length of several important species (bocaccio, chilipepper, blue rockfish, widow rockfish, and yellowtail rockfish) reached a maximum in 1982–83 from both growth of young fish and accumulation of larger fish from abundant year classes produced in the mid-1970's or earlier (Beamish, 1993; Rogers and Bence[5]; Ralston et al.[6]). For example, large chilipeppers (40–50 cm) composed half of the chilipepper catch in 1977–78. Chilipeppers of this size, estimated at 7–15 years old by von Bertalanffy age-at-length equations (Rogers and Bence[5]), were produced before 1971, when both recreational and commercial fishing was less intense. In the first few years that CPFV's fished in deep water, many locations had accumulations of large fish. Fishing pressure, as indicated by landings of rockfish, peaked in 1982 in the Monterey Bay area for both CPFV (Fig. 3a) and commercial fisheries. As fishing pressure increased, large fish were caught and removed more rapidly than they were replaced, and smaller fish dominated the catch. CPFV's could no longer find locations with unexploited populations of large fish. The proportion of large fish in the catch dropped from 1983 to 1985 as indicated by the reduced size of the 90th percentile of bocaccio, chilipepper, yellowtail rockfish, canary rockfish, and widow rockfish. Declining mean lengths for bocaccio and chilipepper in the trawl and gillnet fisheries indicated fewer large fish in commercial fisheries as well (Fig. 8).

Although both CPFV's and commercial fisheries remove large rockfish, their relative impact differs among species. Bocaccio are heavily exploited by commercial fisheries; their annual take for 1982–94 has been estimated at 20–30% of the biomass, and by 1994 the estimated biomass had dropped to about 17% of its 1980 level (Ralston et al.[6]). Bocaccio has experienced the most dramatic decline in biomass of the commercial rockfish species in the Monterey Bay area, but sustained fishing pressure has also resulted in decreased mean lengths of commercially caught chilipepper and widow rockfish (Fig. 8) and reduced the availability of large fish to CPFV's.

The larger deepwater species (bocaccio and chilipepper) are harvested mostly by the commercial fisheries. Average estimated percent landed by CPFV's of the combined CPFV and commercial landings for 1980–94 are displayed in Table 4. CPFV's took no more than 18% of chilipepper and 27% of bocaccio in any year. CPFV's also took less widow rockfish than were taken by commercial fisheries.

Shallower species such as blue rockfish have been taken primarily by the recreational fishery. CPFV's also took a high percentage of mid-depth yellowtail rockfish and canary rockfish; these species are commonly caught by commercial trawlers at ports farther north, but yellowtail rockfish averaged only 5% and canary rockfish only 0.5% of the commercial rockfish catch in the Monterey Bay area from 1980 to 1994. Thus, CPFV landings have a large local impact on blue, yellowtail, and canary rockfish, but commercial fisheries have a greater effect on bocaccio, chilipepper, and widow rockfish.

Increased natural mortality as well as increased fishing mortality during the northern El Niño of 1982–83 may have reduced the proportion of large rockfish. Yellowtail rockfish and widow rockfish grew more slowly, and yellowtail rockfish, chilipepper, and blue rockfish weighed less relative to their length during strong El Niño events (Lenarz et al., 1995; VenTresca et al., 1995). These species appear to be stressed when changes in ocean circulation reduced the nutrient levels and available food. Zooplankton volumes were reduced in 1982–83 (McGowan, 1985), and primary productivity and euphausid abundance were below normal during the 1992 El Niño (Lenarz et al., 1995). The pattern of strong upwelling alternating with periods of onshore advection, important to the production of macrozooplankton prey for blue rockfish (Hobson and Chess, 1988), was disrupted during the 1982–83 El Niño (Norton et al., 1985). These factors indicate reduced prey for rockfish, which increased feeding stress, decreased their fitness, and may have increased mortality. The lack of food may have also made rockfish of all sizes more vulnerable to CPFV hook and line fishing; overall catch per unit of effort was highest in 1982–83.

In addition to increased natural mortality of adults, El Niño environmental conditions also reduced first-year recruitment of most rockfish species (Lenarz et al., 1995). Wide variations in abundance of young-of-the-year recruits have been observed over 10 years from both midwater juvenile trawls and from *in situ* counts of settled juveniles (Ralston and Howard, 1995). Years such as 1983 with high sea surface temperatures produce particularly poor year classes for most rockfish species studied. Recruitment for many of these species improved after the El Niño; average oceanic conditions returned producing a surge of young-of-the-year in 1984 and 1985. These year classes first appeared in the fishery as drops in the 10th percentile and mean length. Bocaccio, the fastest growing species, was the first to appear in the fishery with a few small fish in 1985 and more in 1986. Chilipepper appeared in 1986–87, and yellowtail rockfish in 1987–88. The growth of these new recruits was the dominant

Table 4.—Estimated percentage of weight taken by CPFV's from combined commercial and CPFV landings 1980–94. Values adjusted for under-reporting of catch in CPFV logbooks.

Common name	Scientific name	Weight taken (%)
Blue rockfish	*S. mystinus*	83
Yellowtail rockfish	*S. flavidus*	40
Chilipepper	*S. goodei*	9
Bocaccio	*S. paucispinis*	9
Widow rockfish	*S. entomelas*	11
Greenspotted rockfish	*S. chlorostictus*	65
Canary rockfish	*S. pinniger*	63

[6] Ralston, S., J. N. Ianelli, R. A. Miller, D. E. Pearson, D. Thomas, and M. E. Wilkins. 1996. Status of bocaccio in the Conception /Monterey/ Eureka INPFC areas in 1996 and recommendations for management in 1997. *In* J. Glock and S. K. Krause (Editors), Appendix Volume 1: Status of Pacific groundfish fishery through 1996 and recommended acceptable biological catches for 1997: Stock assessment and fishery evaluation, p. B1–B48. Pac. Fish. Manage. Counc., Portland, Oreg.

cause of increasing mean lengths until 1991.

Variable success of year classes is a significant characteristic of rockfish populations (Leaman and Beamish, 1984). Several dominant rockfish species in the CPFV catch, especially chilipepper, bocaccio, yellowtail rockfish, and widow rockfish, recruited strongly to the fishery in 1977–80 from year classes produced in the mid-1970's, and in 1985–87 from 1984–85 year classes. The fishery appears to have depended on these strong recruitment events for most of the catch after 1984 (Fig. 7). Strong recruitment pulses are not apparent in the less heavily targeted rockfish species such as olive, greenstriped, greenspotted, and rosy rockfish, because they have a reserve of older year classes to buffer the effect of new recruitment. Without the reserve of older fish, the targeted species are highly vulnerable to recruitment variability.

Recruitment success may vary with environmental conditions between decades as well as between years. Ocean surface temperature off California changed from below average to above average around 1976 (Smith, 1995). This change produced more than a decade of warm conditions that may have limited recruitment of colder-water species to central California, similar to the reduced recruitment of blue rockfish and olive rockfish at the edge of their range in southern California during 1978–81 (Stephens et al., 1984). So instead of a few years between successful recruitment, some species may have experienced longer periods with little recruitment (Hollowed and Wooster, 1995). The accumulated larger bocaccio, chilipepper, yellowtail rockfish, and blue rockfish in 1977–83 may have been the product of several years of successful recruitment during the colder years before 1976. Relatively large year classes appear to be less frequent after 1985.

Rockfish are generally long lived, with over half of the species reaching maximum ages of 60 years or more (Love et al., 1990). They take an average of 5 years to reach sexual maturity (Wyllie Echeverria, 1987). The prolonged reproductive phase for unexploited populations (from about age 5 to 60) serves as a buffer against periods of recruitment failure due to environmental variations (Leaman and Beamish, 1984). In the CPFV fishery, half of the catch of the large rockfish species (bocaccio, chilipepper, yellowtail rockfish, and widow rockfish) and 90% of canary rockfish are now taken before sexual maturity. Only smaller species such as rosy and greenstriped rockfish usually reach sexual maturity before they are caught. Fishing down the reservoir of older, sexually mature fish removes the buffer and increases the risk of prolonged recruitment failure.

A similar decline in the availability of large rockfish was noted by Love et al. (1998) in the Southern California CPFV catch. They noted a dramatic decline in the catch from 3.0 to 0.4 rockfish per hour for 21 target species from 1980 to 1996, and they noted a shift from predominantly larger species to smaller species. The catch rate declined for most large species including bocaccio and chilipepper, and the mean size declined for several large species including chilipepper, vermilion rockfish, copper rockfish, and greenspotted rockfish. They noted a lack of adult fish in the catch of several species. These changes in Southern California indicate the declining size and availability of rockfish in California is widespread and not localized to the Monterey Bay area.

Fishery managers should be concerned for the health and sustainability of species with mean length at or below that of maturity. Bocaccio, chilipepper, yellowtail rockfish, and canary rockfish all fall into this category in the Monterey Bay area. If significant new recruitment is the cause of the recent declines in mean size, it should be traceable in the length frequency modes of fish from 1994 onward. If there is no strong mode of young fish, we must assume that recruitment is not keeping up with removals by the combined recreational and commercial fisheries.

Summary

The mean length of rockfish caught in the late 1970's increased as CPFV's moved into deeper water. The mean length was generally larger for deepwater species than for shallow-water species, and large individuals were caught from 1977 through 1983. A surge of new recruitment after the 1982–83 El Niño produced a sharp drop in mean length of several important species and a decline in combined rockfish mean length. Mean lengths did not recover to the high levels of 1982–83 despite the growth of these recruits and the continued emphasis on deepwater species through 1991.

Fish were harvested by both the CPFV and commercial fisheries at smaller sizes after 1982, and mean length and total landings have dropped in both fisheries. CPFV's shifted back toward shallow water as the difference in size between the deepwater and shallow-water species decreased in 1992–94. The mean length of bocaccio, chilipepper, and yellowtail, canary, and blue rockfish caught on CPFV's has dropped below the size at which 50% of the females mature.

Since 1984, the period between highly successful recruitment events seems to have been longer for the dominant species in the catch, and recruits have been harvested by CPFV's and commercial fisheries (depending on species) at smaller sizes than in the past, within a few years of entering the fishery. Since new recruits often appear in the CPFV catch at least 1 year ahead of the commercial catch, the CPFV fishery could serve as an indicator of the relative strength of new recruitment.

Acknowledgments

This study would not have been possible without the conscientious work of many CDFG sportfish samplers and biologists over the years, especially Daniel Miller and Daniel Gotshall. I thank Linda Garrett for assembling and editing the data for this report. I thank Richard Parrish, Jerry Norton, Mark Helvey, Debra Wilson-Vandenberg, and Julie Olfe for their helpful comments on the manuscript, and Tone Nichols for her graphics expertise.

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Mortality of Lingcod, *Ophiodon elongatus*, Related to Capture by Hook and Line

DOUGLAS ALBIN and KONSTANTIN A. KARPOV

Introduction

The lingcod, *Ophiodon elongatus*, is a large carnivorous fish of the family Hexagrammidae inhabiting the eastern Pacific Ocean from Alaska to Baja California (Miller and Lea, 1972). Its life cycle is entirely marine, with egg masses laid during winter on rocky habitats, typically in areas of surge or current. The male lingcod defends the nest from egg-eating fishes (Low and Beamish, 1978). Larvae and early juveniles are found in pelagic waters during the spring months, while juveniles of about 7–35 cm length inhabit nearshore sandy areas. Larger lingcod are typically found on rocky reefs at depths to 420 m (Miller and Geibel, 1973).

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ABSTRACT—Lingcod, Ophiodon elongatus, *were captured by hook and line (sport rod and reel gear and commercial troll gear) at two coastal California locations and held in aquaria for periods of up to 32 days for evaluation of capture-related mortality. Three of 69 lingcod captured with rod and reel gear died of capture-related injuries (4.3% mortality; 95% confidence interval 0–9.3%). None of 15 lingcod captured with troll gear died of capture-related injuries. Due to the low overall mortality rate, there were no discernable trends in mortality with respect to sex, length, depth of capture, and terminal tackle (bait vs. lure). Of 38 fish with visible hooking wounds, 26 showed evidence of wound healing during the holding period.*

Lingcod are taken in significant numbers by marine recreational and commercial fisheries in California (Fig. 1) and other Pacific coast states (Karpov et al., 1995; PFMC[1]). Management measures for lingcod include bag limits and minimum size limits for recreational fisheries, and catch quotas and minimum size limits for commercial fisheries. A minimum size of 56 cm (22 in) total length was applied to California's recreational fishery in 1981. In 1998 a limit of 61 cm (24 in) total length was applied to all recreational and commercial fisheries of California, Oregon, and Washington.

The portion of captured fish released live from California's recreational fishery has risen from about 10% in 1981 to about 40% in recent years (Fig. 2). Such high return rates suggested that mortality of released lingcod should be determined and, if significant, should be included in stock assessment estimates of total fishing mortality as recommended by Clark (1983).

During the past few decades, a general trend of increasing harvest pressure on fishery resources has given rise to increasing use of fishery management regulations requiring release of some (size limits) or all (catch-and-release only recreational fishing) fish captured. Additionally, many recreational anglers voluntarily return some or all fish captured as a conservation measure.

Muoneke and Childress (1994) reviewed studies, popularly called "hooking mortality" studies, evaluating mortality to fish that are hooked, landed, handled, and released. Most of the studies were conducted in fresh water and pertained to salmonids, centrarchids, or percids; mortality rates ranged from 0 to 88%.

In marine environments, Wertheimer et al. (1989) found a mortality range of 18.5–26.4% for chinook salmon, *Oncorhynchus tshawytscha*, held 4–6 days after capture by commercial trolling gear. Gjernes et al. (1993) found mortality rates of 30% for chinook salmon and 14% for coho salmon, *O. kisutch*, held less than 1 day after capture by recreational anglers. Diodati and Richards (1996) evaluated capture and release mortality of striped bass, *Morone saxatilis*, by conducting experimental angling in a 2 ha saltwater impoundment; mortality for captured fish was 9% over a 58-day period. At the end of the experiment the impoundment was drained; condition factor was significantly lower in surviving captured fish than in surviving fish that had not been captured. Bugley and Shepherd (1991) estimated capture and release mortality to black sea bass, *Centropristis striata*, by holding captured fish in wire cages on site for 48 h; mortality was 4.7%.

Ideally, the holding period in a hooking mortality study should last more than a few days because fish captured

[1] PFMC. 1996. Status of the Pacific coast groundfish fishery through 1996 and recommended acceptable biological catches for 1997: stock assessment and fishery evaluation. Pac. Fish. Manage. Counc. 2130 S.W. Fifth Ave., Suite 224, Portland, OR 97201.

and released in apparently good condition can expire days later. Delayed mortality can occur from hooking wounds, disease, or osmoregulatory dysfunction (Muoneke and Childress, 1994).

Methods

Our general approach was to capture lingcod using traditional hook and line gear and then hold them in aquaria as long as practical to observe their general condition and the condition of any wounds arising from capture. When a fish became ill or died, we attempted to attribute the illness or death to either a) physical injuries and stress incurred during capture or b) injuries and stress incurred as a result of holding the fish for evaluation.

Monterey County

During 24–29 September 1995, 15 lingcod were captured and held aboard the California Department of Fish and Game vessel RV *Mako* off Monterey County (Fig. 3). Using sonar, schools of fish were located over rocky habitats at depths <50 m. The vessel was then drifted over the schools, and anglers fished with conventional recreational rod and reel gear, mainly with large baits or lures intended to target lingcod. Baits were predominately live market squid, *Loligo opalescens*; live jack mackerel, *Trachurus symmetricus*; or live Pacific sardine, *Sardinops sagax*. All hooks had a typical single barb on the point. Nearly all hooks had a gap distance from the point to the shank of 18–20 mm and were single hooks; however, some anglers occasionally used somewhat larger or smaller hooks or treble hooks.

To enable identification of individual fish during the holding period, captured lingcod were tagged with model FD-94 numbered yellow anchor tags[2] anchored in the dorsal musculature between proximal pterygiophores. Fork length, sex (based on external genitalia), depth of capture, and terminal tackle (bait or lure) were recorded. Tackles with bait attached to a lure were recorded as bait.

Lingcod surviving immediate capture were placed in an onboard flow-through live well measuring 1.5 × 1.5 × 2 m. A habitat structure consisting of nine 102 mm diameter plastic pipes about 0.7 m long, bundled together, was placed in the live well to give the lingcod an opportunity to stabilize themselves within crevice-like locations and isolate themselves from one another. Lingcod in the live well were evaluated daily for condition and mortality and fed small live rockfish (*Sebastes* spp.) and other live baits to satiation in order to provide nutrition and discourage cannibalism.

On 29 September, 10 of the surviving lingcod and the habitat structure were transferred to Monterey Bay Aquarium where they were held in a 1.2 × 1.2 × 1.2 m continuous flow aquarium 18 days for further observation. Daily, they were evaluated and fed dead market squid to satiation.

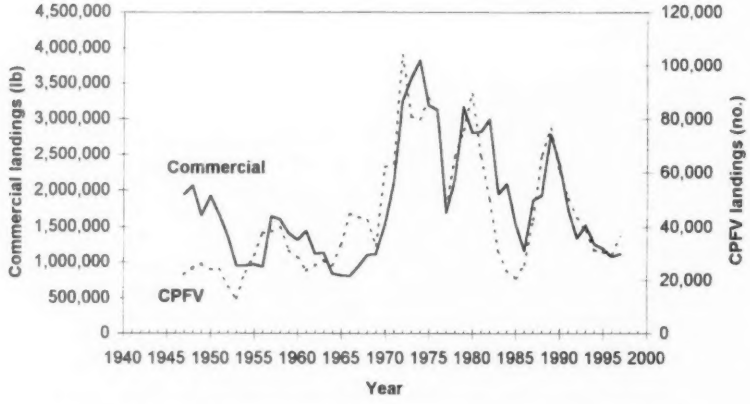

Figure 1.—California lingcod catch by commercial fisheries (California Department of Fish and Game landing receipt data) and commercial passenger fishing vessels (CPFV) (California Department of Fish and Game vessel log data).

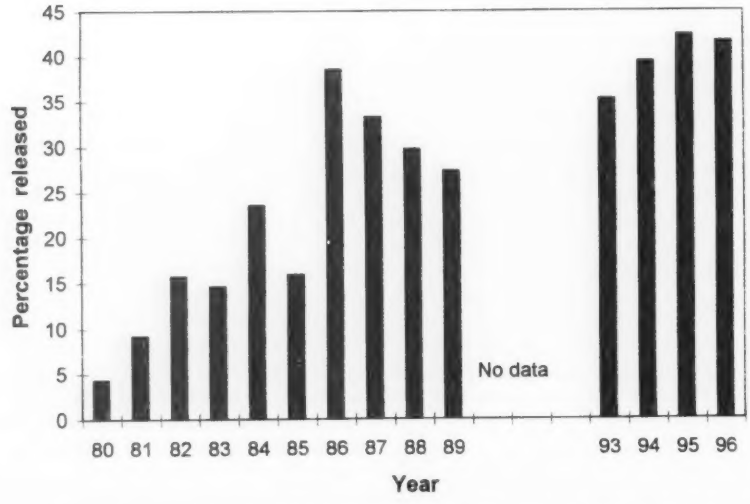

Figure 2.—Percent of California's recreational lingcod catch released alive (Pacific States Marine Fisheries Commission RecFIN data).

[2] Floy Tag and Manufacturing Inc., Seattle, Wash. Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

Mendocino County

During January–August 1996, 69 lingcod were captured from Mendocino County waters (Fig. 3) from Department of Fish and Game vessels and chartered commercial fishing vessels. The lingcod were captured as part of a multipurpose nearshore reef fish tagging study. Again, sonar was employed to locate aggregations of fish over rocky habitats. Since a main purpose of the fishing was to capture rockfish for tagging and release with minimal injury, depths fished were usually less than 30 m, and bait was seldom used. Lingcod >61 cm total length were generally not retained because mortality to fish near or below the minimum size limit was of greatest interest. Rod and reel was the gear used on the multipurpose reef fish tagging trips. However, trolling gear was also used on two special trips targeting lingcod to evaluate mortality resulting from that gear and also to evaluate mortality of fish caught from depths >30 m.

The Mendocino County lingcod were tagged with dorsal anchor tags, like the Monterey County fish, or with 5 × 17 mm oval disk tags[2] attached to the opercular bone with fabric basting tacks.[3] Gear, depth of capture, hook location, fork length, and sex were recorded. The fish were held in onboard flow-through live wells and transported to the Fort Bragg High School Marine Laboratory at the end of the day. At the laboratory, the lingcod were segregated by size into different 1,000 l aquaria to minimize predation. Bundled plastic pipes were placed in the aquaria to provide habitat structure. Three times per week, the lingcod were observed and fed dead market squid or anchovy, *Engraulis mordax*, to satiation.

In both Monterey and Mendocino counties, the anglers (mainly Department of Fish and Game biologists or commercial fishermen) were instructed to handle the lingcod with the same care they would if they were recreational fishing. Some individuals wore rubber gloves to handle the fish, but most did not. The fish were not anesthetized for handling, so fish occasionally squirmed free and landed on the deck.

[3] Quiltak Inc., Flagstaff, Ariz.

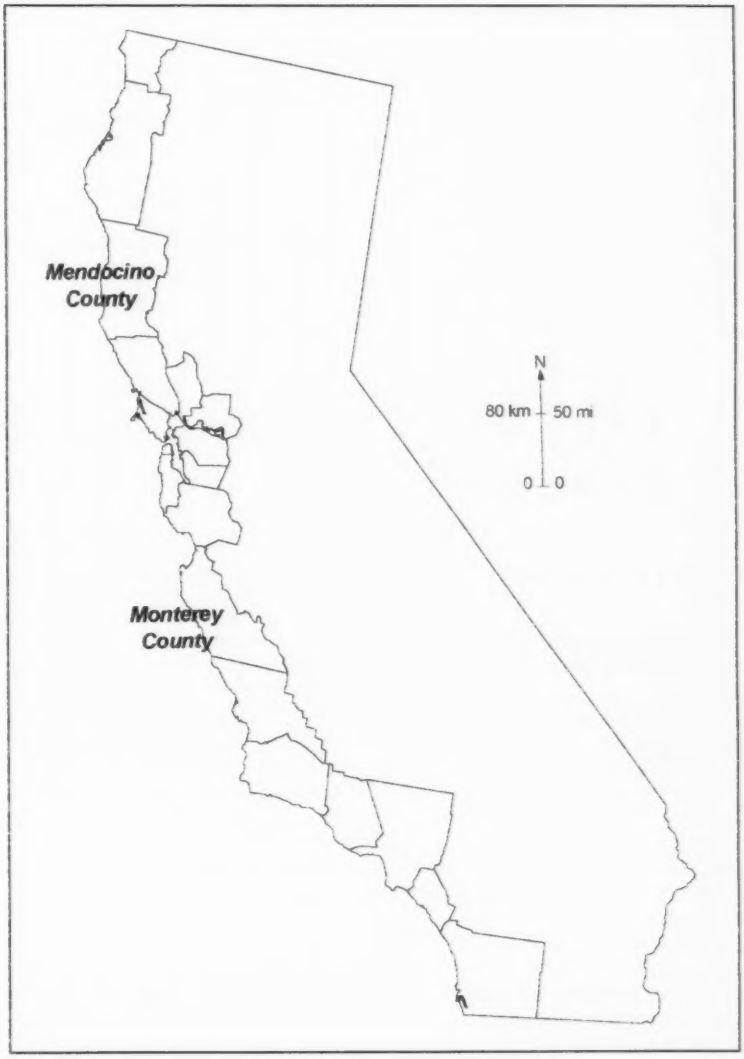

Figure 3.—Mendocino and Monterey counties, Calif.

The holding period for fish that survived immediate hooking and landing ranged from 2–32 days ($\bar{x}$ = 15 days). At the end of the holding period, surviving lingcod were given a final examination and released to the ocean.

Results

Of the 84 lingcod captured, 65 were males, 17 were females, and the sex of two was not determined (Table 1). Fork length of males ranged from 355 to 686 mm; fork length of females ranged from 279 to 670 mm (Fig. 4). Capture depths ranged from 6 to 64 m.

Three fish died during the holding period (Table 1). Of those three, one died of causes clearly attributable to capture. That fish, number 7, suffered a puncture wound to the ventral aorta when it was hooked and bled to death on landing. Another fish, number 60, died while being transported to the Fort Bragg High School Marine Laboratory,

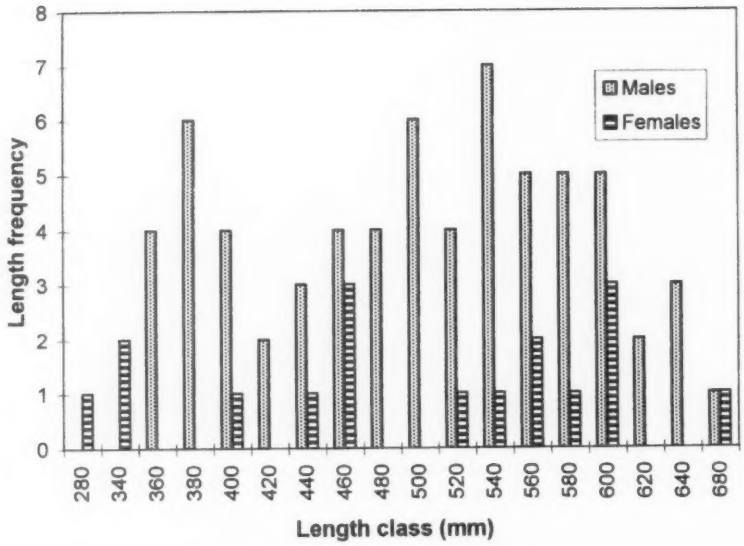

Figure 4.—Sex and length frequency composition of captured lingcod.

and another, number 48, died while being transported back to the ocean for release.

Fish number 43 survived the holding period but was very lethargic on release. It had developed an infection in the eye region where it had been punctured by the hook when captured. We assume fish number 43 did not survive long following release, and we attribute its death to injuries sustained during capture.

The deaths of fish numbers 48 and 60 were not attributable to any apparent physical injuries, and were probably due to physiological stress from being handled. Since fish 48 died 4 days after its capture and was handled shortly before death, we do not attribute its death to handling stress incurred during capture. Fish 60 died about 6 h after it was captured. Handling stress from capture probably contributed to its death because stress-induced blood parameter changes in fish can remain at least 6 h (Novak[4]). At 279 mm fork length, it was the smallest lingcod captured in the study. We conclude that, of the 84 fish captured, capture-related injuries caused the death of three fish (numbers 7, 43, and 60); cause was generally not difficult to discern.

All three of the capture-related mortalities were captured with rod and reel gear. The mortality rate for rod and reel gear is therefore 3/69 = 4.3%. For the binomial mortality rate (p), the variance (v) can be computed as

$$v = pq/n,$$

where $q = 1\text{-}p$ and n is the sample size (Sokal and Rohlf, 1969). Assuming a normal approximation to the binomial distribution, the 95% confidence interval for the rod and reel mortality rate is 0–9.3%. None of the 15 lingcod captured with troll gear died of capture-related injuries.

Discussion

Due to the low overall mortality rate relative to the sample size, it is not possible to statistically isolate the effects of capture depth, terminal tackle, fish length, and sex on mortality. Much larger sample sizes would be needed to study those factors.

The three fish that died due to capture-related injuries were taken from a range of depths (6, 20, and 27 m). Fish were brought up from depths as great as 64 m with no signs of barotrauma (e.g. gas bubbles in the eyes). Lingcod lack a swim bladder and apparently do not suffer adverse gas expansion effects.

Fork lengths of the three capture-related mortalities were 279, 337, and 627 mm, an indication that smaller lingcod might prove to be more sensitive to capture-related mortality given a larger sample size. We noted capture-related wounds, typically hook punctures in the mouth area, in 38 of the fish held. In 26 of the 38 we observed evidence of healing (e.g. cessation of bleeding, smaller wound diameter) during the holding period. Wounds observed not healing were typically tears in poorly vascularized membranous tissues around the mouth.

Conclusions

Lingcod generally tolerated capture and handling well despite decompression, handling with nets and bare hands, and occasionally being dropped on the deck. Delayed mortality did not prove to be of significant concern. These results support the reputation of lingcod as a relatively hardy species and the use of a minimum size limit as a management tool.

Acknowledgments

We thank the following individuals and organizations for their assistance. On the Monterey coast, skipper Mark Kibby and the crew of the RV *Mako* assisted in capturing and holding lingcod, along with Bob Hardy, Shawn Melton, Paul Reilly, Connie Smithberg, and Carrie Wilson. The Monterey Bay Aquarium provided holding tank space for extended observation of captured lingcod, and Dave Lindquist provided feeding and care. On the Mendocino coast, the Salmon Trollers Marketing Association, through a grant from the U.S. Department of Commerce Northwest Emergency Assistance Program (NEAP), captured lingcod. Holding aquaria were provided by the Fort Bragg High School Marine Laboratory with the support of Fred Rubin. Cat Talbot and Pamela Wright assisted in transporting, evaluating, and caring for captured lingcod. Peter Kalvass edited the manu-

[4] K. Novak, D.V.M. 1996. Fish veterinarian, 700 N. Franklin St., Fort Bragg, CA 95437. Personal commun.

Table 1.—Lingcod captured by hook and line gears and held for mortality observations.

Fish no.	Capture date	Capture gear	Terminal tackle	Capture depth (m)	Fork length (mm)	Sex	Days held	Capture-related mortality	Holding-related mortality	Wounds observed healing
1	9/24/95	Rod & reel	Bait	18	508	M	6			
2	9/24/95	Rod & reel	Lure	27	503	M	23			Yes
3	9/24/95	Rod & reel	Bait	23	602	M	6			Yes
4	9/25/95	Rod & reel	Bait	37	598	F	22			Yes
5	9/25/95	Rod & reel	Lure	37	416	M	22			Yes
6	9/26/95	Rod & reel	Lure	20	521	M	21			No
7	9/26/95	Rod & reel	Lure	27	337		0	X		
8	9/26/95	Rod & reel	Bait	27	453		21			Yes
9	9/26/95	Rod & reel	Lure	9	670	F	21			No
10	9/27/95	Rod & reel	Bait	27	435	M	20			No
11	9/27/95	Rod & reel	Bait	23	630	M	3			
12	9/27/95	Rod & reel	Lure	21	600	M	20			Yes
13	9/28/95	Rod & reel	Bait	23	568	M	2			
14	9/28/95	Rod & reel	Bait	23	572	M	19			No
15	9/28/95	Rod & reel	Lure	47	603	F	19			No
16	1/11/96	Rod & reel	Lure	14	462	M	18			
17	1/11/96	Rod & reel	Lure	14	490	M	18			
18	1/11/96	Rod & reel	Lure	14	446	F	18			
19	1/11/96	Rod & reel	Lure	14	544	M	18			
20	1/11/96	Rod & reel	Lure	14	686	M	18			
21	3/1/96	Rod & reel	Lure	13	597	M	27			No
22	3/1/96	Rod & reel	Lure	13	609	M	27			
23	3/1/96	Rod & reel	Lure	13	430	M	27			
24	3/1/96	Rod & reel	Lure	13	509	M	27			Yes
25	3/1/96	Rod & reel	Lure	13	636	M	27			
26	4/5/96	Rod & reel	Lure	13	345	F	20			No
27	4/5/96	Rod & reel	Lure	13	428	M	20			
28	5/6/96	Rod & reel	Lure	27	383	M	15			
29	5/6/96	Rod & reel	Lure	27	355	M	15			
30	5/6/96	Rod & reel	Lure	27	372	M	15			
31	5/6/96	Rod & reel	Lure	27	367	M	15			
32	5/6/96	Rod & reel	Lure	27	378	M	15			
33	5/6/96	Rod & reel	Lure	27	365	M	15			
34	5/6/96	Rod & reel	Lure	27	357	M	15			Yes
35	5/6/96	Rod & reel	Lure	27	514	M	15			
36	5/6/96	Rod & reel	Lure	27	447	M	15			
37	5/6/96	Rod & reel	Lure	27	530	M	15			Yes
38	6/27/96	Rod & reel	Lure	7	498	M	4			
39	6/27/96	Rod & reel	Lure	7	375	M	4			
40	6/27/96	Rod & reel	Lure	8	464	M	4			
41	6/24/96	Rod & reel	Lure	10	484	M	7			
42	6/24/96	Rod & reel	Lure	10	488	M	7			
43	6/19/96	Rod & reel	Lure	6	627	M	12	X		No
44	6/20/96	Rod & reel	Lure	20	378	M	11			Yes
45	6/20/96	Rod & reel	Lure	20	455	F	11			
46	6/19/96	Rod & reel	Lure	6	549	M	12			
47	6/19/96	Rod & reel	Lure	6	543	M	12			
48	6/27/96	Rod & reel	Lure	7	568	M	4		X	
49	6/19/96	Rod & reel	Lure	6	545	M	12			
50	8/5/96	Rod & reel	Lure	18	408	M	11			
51	8/5/96	Rod & reel	Lure	16	481	M	11			Yes
52	8/5/96	Rod & reel	Lure	16	507	M	11			
53	7/30/96	Rod & reel	Lure	20	402	F	17			
54	7/30/96	Rod & reel	Lure	20	589	M	17			
55	7/30/96	Rod & reel	Lure	20	589	F	17			
56	7/30/96	Rod & reel	Lure	20	459	F	17			
57	7/30/96	Rod & reel	Lure	20	408	M	17			
58	7/30/96	Rod & reel	Lure	10	465	M	17			
59	7/30/96	Rod & reel	Lure	12	456	M	17			
60	7/30/96	Rod & reel	Lure	20	279	F	0	X		
61	8/21/96	Bar troll	Lure	40	538	M	9			Yes
62	8/22/96	Bar troll	Lure	55	519	M	8			Yes
63	8/22/96	Bar troll	Lure	55	568	M	8			Yes
64	8/22/96	Bar troll	Lure	55	575	M	8			Yes
65	8/22/96	Bar troll	Lure	55	570	M	8			Yes
66	8/22/96	Bar troll	Lure	55	550	F	8			Yes
67	8/22/96	Bar troll	Lure	55	459	F	8			Yes
68	8/22/96	Bar troll	Lure	55	554	M	8			Yes
69	8/22/96	Bar troll	Lure	55	567	M	8			No
70	8/22/96	Bar troll	Lure	55	608	M	8			Yes
71	8/22/96	Bar troll	Lure	55	595	F	8			Yes
72	8/22/96	Bar troll	Lure	55	480	M	8			Yes
73	8/22/96	Bar troll	Lure	55	549	F	8			Yes
74	8/21/96	Bar troll	Lure	64	525	F	9			No
75	8/21/96	Bar troll	Lure	40	540	M	9			Yes
76	8/14/96	Rod & reel	Lure	15	378	M	16			Yes
77	9/19/96	Rod & reel	Lure	26	556	F	32			
78	9/25/96	Rod & reel	Bait	9	588	M	26			
79	9/27/96	Rod & reel	Lure	13	519	M	24			No
80	9/27/96	Rod & reel	Lure	13	611	M	24			
81	9/27/96	Rod & reel	Lure	13	639	M	24			Yes
82	9/27/96	Rod & reel	Lure	13	397	M	24			
83	9/27/96	Rod & reel	Lure	13	400	M	24			No
84	9/27/96	Rod & reel	Lure	13	333	F	24			

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